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SUSTAINABILITY LOGISTICS BASING SCIENCE AND TECHNOLOGY OBJECTIVE – DEMONSTRATION; SELECTED TECHNOLOGY ASSESSMENT

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14. ABSTRACT
During the period October 2016-June 2017, the U.S. Army Natick Soldier Research Development and Engineering Center (NSRDEC) collected and assessed information on system attributes of selected technologies related to the objectives of Sustainability Logistics Basing Science and Technology Objective – Demonstration (SLB-STO-D). The goal of the SLB-STO-D is to demonstrate emerging materiel solution technologies and associated non-materiel solutions that can reduce the need for fuel resupply by 25%, for water resupply by 75%, and for waste removal by 50%, while maintaining or improving the quality of life at expeditionary base camps. The technologies that are the subject of this report were down-selected for inclusion in the SLB-STO-D portfolio and are included in the Integrated Solution Sets that satisfy the STO-D challenge. Most of these technologies participated in previous field data collection events at operational base camp venues. These selected technologies are in various stages of maturity along their individual acquisition life cycles. This assessment, called the Selected Technology Assessment, highlights the system-level attributes of these technologies and identifies areas of promise and areas for improvement. This Technical Report documents the objectives, technologies, methods, and results of the SLB-STO-D Selected Technology Assessment.

15. SUBJECT TERMS

COSTS	ENERGY	GRAYWATER	TECHNOLOGY	DEMONSTRATIONS
FUELS	GENSETS	BASE CAMPS	ENVIRONMENTS	REDUCED FOOTPRINT
WASTE	KITCHENS	RELIABILITY	QUALITY OF LIFE	CONTINGENCY BASING
POWER	BASELINE	AVAILABILITY	SUSTAINABILITY	TEST AND EVALUATION
WATER	LOGISTICS	SOLID WASTES	ARMY PERSONNEL	TECHNOLOGY ASSESSMENT
IMPACT	REDUCTION	WASTEWATER	MAINTAINABILITY	HUMAN SYSTEMS INTEGRATION

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EXECUTIVE SUMMARY

The report covers work done for the Sustainability Logistics Basing – Science and Technology Objective – Demonstration (SLB-STO-D)[1] from the period of October 2016 to September 2017.

The SLB-STO-D is a Research Development and Engineering Command (RDECOM) program executed by the Natick Soldier Research Development and Engineering Center (NSRDEC) that seeks to enable independence and self-sufficiency and reduce sustainment demands at contingency bases. The Army's need to reduce the sustainment demands (i.e., fuel and water consumption and waste generation) at contingency bases is driven by the imperative to minimize the number of resupply convoys and associated ground and air protection. This ultimately reduces the exposure hours for Soldiers subject to life threatening scenarios such as direct enemy attack and improvised explosive devices. In addition, the rising costs of resupplying expeditionary forces and conducting waste backhaul will be greatly reduced.

The SLB-STO-D project intended to reduce the costs and risks associated with the increasing resupply and logistical burden at expeditionary bases by developing and integrating technologies along with non-materiel solutions that demonstrate an optimized integrated approach to reducing sustainment requirements for small contingency base operations. The programmatic goals of the SLB-STO-D were to reduce fuel consumption by 25%, water consumption by 75%, and waste generation by 50%, while maintaining or improving the quality of life of Soldiers at expeditionary bases in the size range of 50–1000 personnel. The SLB-STO-D successfully demonstrated how these goals can be achieved in fiscal year (FY)17.

To resolve the challenges, the SLB-STO-D formulated an integrated Model-Based Systems Engineering (MBSE) approach for technologies and non-materiel solutions to address the problem statement. To this end, the SLB-STO-D program used modeling, simulation, and analysis to demonstrate reductions in fuel, water, and waste (FWW) while maintaining a Force Provider-like operational Quality of Life (QoL(O)). The reductions will be achieved through the implementation of materiel and non-materiel solutions that are compared to an FY12 Operationally Relevant Technical Baseline (ORTB), which established a point of comparison of FWW for base camps with 50, 300, and 1,000 personnel.

This report focuses on those materiel solutions, i.e., technologies, which showed promise in reducing the FWW quantities in demonstration, modeling, and simulation. The technologies were organized into Integrated Solution Sets (ISS) that collectively reduced the FWW quantities in the base camps and met the reduction goals. As part of the SLB-STO-D's capstone effort, the Experimentation, Demonstration, and Validation Team (EDVT) was directed by the Core Leadership Team (CLT) to conduct a Selected Technology Assessment of the systems down-selected into the ISS.

The EDVT developed a deliberate step-wise process to execute this task. The steps are detailed in Chapter 2 of this report and included identifying and defining the attributes, collecting attribute data from Technology Providers, developing value curves for attributes, then scoring

[1] Formerly known as Technology-Enabled Capability 4a (TECD 4a) Sustainability/Logistics-Basing.

the attributes and conducting the analysis. The CLT and the EDVT met with each of the partner Research, Development, and Engineering Centers in turn at their respective locations. The Technology Providers did an excellent job providing data for system attributes. The Maneuver Support Battle Lab at the Maneuver Support Center of Excellence developed and executed the scoring protocols and analysis. The output of this analysis, i.e., the results, are documented in Chapter 3 of this report, supported by the data cataloged in Annex B. This information can be useful for both Materiel Developers and Capability Developers.

For Materiel Developers, this assessment of research and development technologies has identified some areas that indicate promise and some areas that indicate more work is required. The selected technologies are at various stages in their developmental cycle. Through field demonstration and this assessment, the SLB-STO-D has helped identify what works well, and some features that do not yet work as well as desired. Materiel Developers can use this information to focus efforts and aid in funding decisions. Some of the technologies featured in the ISS are funded for further development while some are not. Many of the systems have in place technology transition plans, but some do not, where perhaps they should.

For Capability Developers, this assessment may assist with requirements generation, training development, and base camp doctrine, e.g., base camp design considerations. The system attribute data gives clues to agencies of the Training and Doctrine Command and the various Combatant Commanders for future DOTMLPF (doctrine, organization, training, materiel, leadership, personnel, and facilities) considerations related to contingency base camp planning and execution.

The research and analysis methodology developed for this assessment can be repeated for any similar project. The chosen attributes can be adjusted based on the scope and needs of the project.

SUSTAINABILITY LOGISTICS BASING SCIENCE AND TECHNOLOGY OBJECTIVE – DEMONSTRATION; SELECTED TECHNOLOGY ASSESSMENT

1. INTRODUCTION

This technical report documents the methodology and findings of Task #18 from the Sustainability/Logistics-Basing Science & Technology Objective-Demonstration (SLB-STO-D) project's Integrated Master Schedule. During the period from October 2016 to June 2017, the Natick Soldier Research, Development and Engineering Center (NSRDEC) collected and assessed information on system attributes of selected technologies related to the SLB-STO-D's objectives.

1.1 SLB-STO-D Program

In 2010, the Army recognized the need to reduce sustainment demands at contingency bases. Contingency bases are highly dependent on resupply, which can be unpredictable, put Soldiers at risk in convoys, and impact mission completion. It is too costly and labor intensive for a small unit (platoon, company, or battalion) to transport and maintain all required consumables (fuel and water) to last for weeks or months at small base camps. In 2011, the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology charged the U.S. Army Research Development and Engineering Command (RDECOM) with conducting a Technology-Enabled Capability Demonstration (TECD) 4a - Sustainability Logistics Basing (SLB), now programmed as a Science and Technology Objective – Demonstration (STO-D), to develop, collaborate, and execute a program that would address these sustainment challenges.

> *"The Army needs improved capability to enable sustainment independence by reducing resupply and backhaul demand at contingency base camps. The FY12 to FY17 objective is to reduce the need for fuel resupply by 25%, reduce the need for water resupply by 75%, and decrease waste generation/backhaul by 50%, while maintaining a Force Provider-like Operational Quality of Life (QoL(O)) at these base camps."*

Current Army maneuver units have limited or no organic basing capability and rely on theater-provided support. Except for the Force Provider suite of systems, the majority of theater-provided equipment support is not standardized, integrated, or optimized to be easily deployed, transported, or erected, and is inherently inefficient. The above-mentioned problem statement forms the basis for the program and lays the foundation for the formulation of the program execution plan and is pervasively present in the program baseline.

The challenge was to formulate an integrated Model-Based Systems Engineering (MBSE) approach for both technologies and non-materiel solutions to address current Army contingency basing barriers. The SLB-STO-D program used modeling, simulation and analysis to show a

reduction in fuel resupply by 25%, a reduction in water resupply by 75%, and a reduction of 50% in waste generated for backhaul at base camps compared to an established technical and operational baseline, while maintaining a Force Provider-like QoL(O). The focus of the SLB-STO-D program is on the 50-, 300-, and 1,000-personnel base camps, where the Army's Science and Technology efforts are most likely to have a greater impact in resource reduction.

1.2 Goal of the Assessment

As stated in the program definition, the SLB-STO-D objective is to reduce fuel resupply by 25%, water resupply by 75%, and waste generated for backhaul by 50% while maintaining a Force Provider-like operational quality of life (QoL(O)). The initial goal of the SLB-STO-D was to examine the Army technology portfolio to find mature technologies that could potentially reduce fuel generation and demand, water production and demand, and waste generation and handling. These mature technologies were exercised in operationally relevant environments during field demonstrations. A key element of the Analytical Framework for the SLB-STO-D was the planning, preparation, and execution of five field demonstrations featuring empirical data collection. Demonstrations were conducted at two different venues – the Base Camp Integration Laboratory (BCIL) in Fort Devens, MA and the Contingency Basing Integration and Technology Evaluation Center (CBITEC) on Fort Leonard Wood, MO. The demonstrations were organized and conducted as shown in **Table 1**.

Table 1: SLB-STO-D Field Demonstration Summary

DEMO	VENUE	TIMEFRAME	# of SYSTEMS
Demo 1, 50-Person Base Camp	BCIL	Sep-Oct 2014	4
Demo 1, 1000-Person Base Camp	CBITEC	Mar-Apr 2015	9
Demo 1, 300-Person Base Camp	BCIL	Jun-Jul 2015	13
Demo 2 (cooler weather)	CBITEC	Feb-Mar 2016	6
Demo 2 (warmer weather)	BCIL	May-Jun 2016	12

It became apparent through the demonstrations that just looking at the attributes of fuel, water, and waste reduction as the only metrics, even though they were the primary objectives, would be an incomplete assessment of the value of the technology to the Army. Moreover, current Army priorities require that Army capabilities support the increase of the maneuver units' level of readiness, agility, adaptability, and resiliency. Not considering the Army priorities and measuring the factors that will contribute to these priorities would have provided an inaccurate measurement of the real value of the technology to the Army acquisition partners. The SLB-STO-D Core Leadership Team (CLT) decided that it was important to develop an assessment methodology to measure other attributes beyond just fuel, water, and waste (FWW) impacts.

The CLT published guidance (CLT, 2016) that directed the Experimentation, Demonstration, and Validation Team (EDVT) to conduct a Selected Technology Assessment (STA) to:

- "…understand other criteria related to these technologies and the base camp they are part of. These attributes may include cost, manpower (especially if a specific military occupational specialty (MOS) is required),

complexity, need for additional or spare parts, maintenance, footprint, etc."

- "…provide a STO-D technology assessment for the technologies in our key Integrated Solution Sets (ISS)."
- "…technology assessment could include criteria such as Technology Readiness Level (TRL), Soldier feedback, lessons learned at the demonstrations, etc."

1.3 Purpose of the Assessment

The purpose of the work is to provide an assessment of other attributes that contribute to the value of the technology when measured against Army priorities. This report, the output of Task #18, can be used by the Army's Materiel Developers to understand the capabilities and attributes of the technologies in the SLB-STO-D's technology portfolio that show a potential of reduction in fuel resupply by 25%, a reduction in water resupply by 75%, and a reduction of 50% in waste generated for backhaul at base camps and other important measures, such as maturity, deployability, and human systems integration, among others (See Section 2.1 for the other attributes). This report can also be used by the Army's Capability Developers to understand the changing nature of future base camps that are more energy-efficient and water-efficient, and to prepare for changes in planning, training, operation, and maintenance as they relate to base camp personnel and equipment.

1.4 Objective of the Assessment

The output of the assessment, chiefly this report, includes system descriptions, data, and information on the system-level attributes, excerpts of Soldier feedback and lessons learned at demonstrations, and a quantitative assessment of attribute achievement.

1.5 Scope of the Assessment

Two main factors defined the scope of the STA – the list of technologies to be examined and the attributes that were considered. The technologies to be examined were defined by those selected for inclusion in the ISS (Langley, 2017). The attributes considered were selected from a number of sources, then grouped functionally to make the research problem manageable (see also Section 2.1).

1.6 Limitations of the Assessment

The chief limitations of this task were (a) the attempt to characterize attribute attainment for this collection of technologies, most of which are still very early in their acquisition, or research and development (R&D), life cycle, and (b) a common definition of the attributes in the absence of approved requirements documents for each system. In some cases it was necessary to predict what the user's actual requirement for the attribute will be and what level of attribute attainment will be possible for a given technology.

Another notable limitation of the assessment was access to base camp subject matter experts (SME). The attribute value curves were developed through the opinions of a very small panel of

three SMEs. The results of the assessment could be different if a larger, more diverse panel of base camp SMEs could have been involved in the assessment.

2. METHODOLOGY

The EDVT developed a 10-step methodology to plan and execute the assessment. The 10 steps were:

Step #1: Identify the attributes

Step #2: Define and scope the attributes

Step #3: Identify the technologies

Step #4: Research the attributes in the technology portfolio workbook

Step #5: Compile available information

Step #6: Notify the tech providers of information requirements

Step #7: Gather the information from the technology providers

Step #8: Evaluate the information

Step #9: Identify missing or inadequate information

Step #10: Repeat the process until satisfied the best, most complete information was included

Each step is discussed in detail in the following sections.

2.1 Identify the Attributes

The number of attributes that could be considered for each technology was considerable and diverse. If there were a discrete, common set of approved requirements documents, e.g., a Capability Development Document (CDD) or a Capability Production Document (CPD), for each technology, then the task would be straightforward. But that was not the case. Instead, the EDVT researched several sources and categories for potential attributes to be considered and put together a proposed pool of candidates.

The CLT developed a **strategy document** for the conduct of this Capstone task. The document proposed some specific attributes. These included:

- Maintenance
- Additional or spare parts
- Manpower
- Complexity
- Interoperability
- Cost/Affordability
- Soldier feedback
- Lessons learned
- Impact of footprint
- TRL

The TRADOC (U.S. Army Training and Doctrine Command) Capability Manager-Maneuver Support (TCM-MS) was working on a draft CDD for the Contingency Basing Utilities System (CBUS) (TCM-MS, 2016) during this research. The following attributes were derived from the **CBUS CDD**:

- Reliability
- Availability
- Maintainability
- Capability
- Deployability
- Manageability
- Sustainability
- Supportability
- Suitability
- Survivability
- Tailorability
- Trainability
- Transportability

The Force Provider Expeditionary (FPE) system has a current CPD from the Combined Arms Support Command (CASCOM) (CASCOM, 2014). Attributes derived from the **FPE CPD** for consideration included:

- Deployability
- Modularity
- Versatility
- Transportability
- Energy
- Power
- Water Management

The mandatory **Key Performance Parameters (KPP)** are included in the "Capability Development Document (CDD) Writer's Guide, version 3.4" (ARCIC, 2016) published by Army Capabilities Integration Center (ARCIC), TRADOC. The KPPs considered appropriate for this task were:

- Sustainment
- System Survivability
- Training
- Force Protection
- Net Ready
- Energy

The **Army Techniques Publication (ATP) 3-37.10 Base Camps** specifies certain principles of base camps. These attributes should pass down to the systems that make up the camp and include:

- Sustainability
- Survivability
- Scalability
- Standardization

Army Regulation (AR) 602-2 Human Systems Integration (HSI) in the System Acquisition Process, requires that the domains of HSI be considered early in the development process. These attributes are:

- Training
- Manpower
- Personnel capabilities
- Human Factors Engineering (HFE)
- System safety
- Health hazards
- Soldier survivability

And finally, a web search turned up a host of other attributes, often referred to as the "forgotten '-ilities'," for consideration:

Accessibility	Executability	Performability	Supportability
Accountability	Extensibility	Portability	Suitability

Adaptability	Evolvability	Practibility	Survivability
Administrability	Fidelity	Practicality	Tailorability
Affordability	Flexibility	Predictability	Testability
Agility	Functionality	Producibility	Traceability
Availability	Integratability	Recoverability	Trainability
Capability	Interoperability	Reliability	Transportability
Composability	Interpretability	Repeatability	Trustability
Configurability	Maintainability	Responsibility	Understandability
Compatibility	Manageability	Reusability	Upgradability
Demonstrability	Mobility	Scalability	Usability
Deployability	Modifiability	Serviceability	Verifiability
Durability	Operability	Stability	Vulnerability

All these various attributes were reviewed and discussed by the EDVT and CLT during a workshop in September 2016. It was evident that many of the attributes were redundant and many could be derived from more than one source. In order for the STA task to be manageable, the SLB-STO-D filtered and grouped a finite set of attributes to be studied. **Table 2** shows a crosswalk of the selected system attributes by source. The first column of attributes under the blue heading were those system characteristics that were prevalent in the sources and deemed meaningful to the scope of the SLB-STO-D.

This list of attributes was further reduced somewhat. The STA task was intended to focus specifically on the system attributes that were not modeled as part of the project's extensive modeling, simulation, and analysis effort, i.e., characteristics other than technical performance. Since the reduction of FWW is the key feature of the modeling effort, the attributes of Energy, Power, and Water Management were dropped from the STA. The dropped attributes are highlighted in grey in the crosswalk. Additionally, the attributes of Capability, Manageability, and Suitability, also highlighted in grey in the crosswalk, were deemed as very general and inherent in other attributes and therefore dropped from the STA task. And finally, the attribute of Force Protection, while very important, was determined to be outside the scope of this assessment and was also dismissed.

The remaining 22 attributes were then grouped into categories where it made sense to do so. The categories and the attributes are shown in **Table 3**. This grouping of attributes was important in Step #8 where the attributes were assessed and scored.

Table 2: Crosswalk of System Attributes by Source

ATTRIBUTE	MSCoE CDD	MANDATORY KPPs	FORCE PROVIDER CPD	HUMAN SYSTEMS INTEGRATION	BASE CAMP PRINCIPLES	SLB-STO-D STRATEGY
Reliability	Reliability					
Availability	Availability					
Maintainability	Maintainability					Maintenance
Capability	Capability					
Deployability	Deployability		Deployability			
Manageability	Manageability					
Sustainability	Sustainability	Sustainment			Sustainability	Addl or spare parts
Supportability	Supportability					
Suitability	Suitability					
Survivability	Survivability	System Survivability			Survivability	
Tailorability, Modularity, Versatility, Scalability	Tailorability		Modularity, Versatility		Scalability	
Trainability	Trainability	Training		Training		
Transportability	Transportability		Transportability			
Force Protection		Force Protection				
Net Ready		Net Ready				
Energy		Energy	Energy			
Power			Power			
Water Management			Water Management			
Manpower				Manpower		Manpower
Personnel capabilities				Personnel capabilities		
HFE, Complexity				HFE		Complexity
System safety				System safety		
Health hazards				Health hazards		
Standardization, Interoperability					Standardization	Interoperability
Cost/Affordability						Cost/Affordability
Soldier feedback						Soldier feedback
Lessons learned						Lessons learned
Impact of footprint						Impact of footprint
TRL						TRL

Table 3: Attributes Grouped by Functional Area

Function	ID#	Attribute
Readiness and Maturity	1.1	TRL
	1.2	Standardization, Interoperability
	1.3	Tailorability, Modularity, Versatility, Scalability
	1.4	Net Ready
Human Systems Integration	2.1	Manpower
	2.2	Personnel Capabilities
	2.3	HFE, Complexity
	2.4	System Safety
	2.5	Health Hazards
	2.6	Training
Survivability	3	Survivability
RAM-SS	4.1	Reliability
	4.2	Availability
	4.3	Maintainability
	4.4	Sustainability
	4.5	Supportability
Force Projection	5.1	Deployability
	5.2	Transportability
Impact of Footprint	6	Impact of Footprint
Cost/Affordability	7	Cost/Affordability
Soldier Feedback	8	Soldier Feedback
Lessons Learned	9	Lessons Learned

2.2 Define and Scope the Attributes

The next step was to define and scope the attributes so all participants in the task had a common understanding of the attribute. Complete information for each attribute is tabulated in Annex A. Summaries of the definitions are shown below.

1.1 TRL: TRLs are a measure of technical maturity. (Defense Acquisition Guidebook Sec 10.5.2.2 (Defense Acquisition University, 2016))

1.2 Standardization, Interoperability: The ability of a system (such as a vehicle, weapon system, shelter system, etc.) to work with or use the parts or equipment of another system.

1.3 Tailorability, Modularity, Versatility, Scalability: Use modular and multifunctional designs. Use modular buildings and trailer units that can be relocated, repositioned, and reused (or easily dismantled) and offer flexibility. Create designs that allow the base camp to easily expand or contract size and levels of service.

1.4 Net Ready: The Net Ready KPP is to ensure new Information Systems (IS) fit into the existing Department of Defense (DoD) architectures and infrastructure to the maximum extent practicable.

2.1 Manpower: The number of military and civilian personnel required, authorized, and potentially available to train, operate, maintain, and support the system. (AR 602-2 para 1-5.b. (1))

2.2 Personnel Capabilities: The human aptitudes, skills, and capabilities required to operate, maintain, and support a system in peacetime and war. (AR 602-2 para 1-5.b. (2))

2.3 HFE, Complexity: The comprehensive integration of human capabilities and limitations into system definition, design, development, and evaluation to promote effective Soldier-machine integration for optimal total system performance. (AR 602-2 para 1-5.b. (4))

2.4 System Safety: The design and operational characteristics of a system that minimize the possibilities for accidents or mishaps caused by human error or system failure. (AR 602-2 para 1-5.b. (5))

2.5 Health Hazards: The systematic application of biomedical knowledge, early in the acquisition process, to identify, assess, and minimize health hazards associated with the system's operation, maintenance, repair, or storage, such as: acoustic energy, toxic substances (biological and chemical), oxygen deficiency, radiation energy, shock, temperature extremes, trauma, and vibration. (AR 602-2 para 1-5.b. (6))

2.6 Training: The instruction and resources required to provide Army personnel with requisite knowledge, skills, and abilities to properly operate, maintain, and support Army systems. (AR 602-2 para 1-5.b. (3))

3 Survivability: System shall provide for and enable operation in degraded electromagnetic and cyber environments; and allow the system to survive and continue to operate in, or after exposure to, a chemical, biological, radiological, or nuclear (CBRN) environment. It will also include resiliency attributes pertaining to the ability of the broader architecture to complete the mission despite the loss of individual systems.

4.1 Reliability: Reliability is the probability that an item can perform its intended function for a specified interval under the stated conditions. ("How long will it work?")

4.2 Availability: Availability is a measure of the degree to which an item is in the operable and committed state at the start of a mission when the mission is called for at an unknown (random) time. ("How ready is the system to perform when needed?")

4.3 Maintainability: Maintainability is the measure of an item's ability to be retained in or restored to a specified condition when maintenance is performed by skilled personnel, using the correct procedures and resources. ("How long does it take to repair?")

4.4 Sustainability: Base camps must be sustainable. This means that base camps achieve and sustain effectiveness within the means of available resources (materials, labor, energy, and funds) and without placing unnecessary strain on existing sustainment systems. Sustainability is primarily achieved through minimizing demand and cost-effective consumption of resources.

4.5 Supportability: Supportability is the degree to which system design characteristics and planned logistics resources meet system peacetime readiness and wartime utilization requirements.

5.1 Deployability: For the purposes of this assessment, deployability will be thought of as the capability of the system to deploy from home station to operational theater.

5.2 Transportability: For the purposes of this assessment, transportability will be thought of as the capability of the system to be transported from the point of debarkation to the contingency base camp where the system will be operated.

6 Impact of Footprint: The size, shape, and location of a technology can have an impact, positive or negative, on base camp management, operations and security.

7 Cost/Affordability: Production costs.

8 Soldier Feedback: During demonstrations Soldiers have been included in familiarization briefings, training, and in some cases, operation of systems. Soldiers have provided their feedback based on these activities.

9 Lessons Learned: Each demonstration included daily reviews of activities and closing After Action Reviews. Technology Providers and SLB-STO-D functional teams discussed lessons learned during these events.

2.3 Identify the Technologies

The scope of the project was to assess those technologies that are included in the ISS developed as a product of the modeling, simulation, and analysis effort. The EDVT coordinated closely with the Modeling, Simulation, and Analysis Team (MSAT), as well as the CLT and the Systems Engineering and Integration Team (SEIT), while the analysis effort was underway to identify as early as possible the list of technologies to be assessed. The final list of subject technologies is shown in **Table 4**. The technologies are grouped according to the modeling focus area for contribution to the FWW savings parameters. The technologies were sponsored by the Army’s various Research, Development, and Engineering Centers (RDECs) including Natick Soldier RDEC (NSRDEC), the Tank Automotive RDEC (TARDEC), the Communications-Electronics RDEC (CERDEC), and the Engineer Research and Development Center (ERDC), plus one system sponsored by the Project Manager Expeditionary Energy & Sustainment Systems (PM E2S2).

Table 4: List of Selected Technologies

ID	Technology/Component	Lab/ RDEC	Focus Area
EE-0290	PowerShade Cost Reduction	NSRDEC	Fuel Reduction - Demand Side
EE-0300	Self-Powered Solar Water Heater	NSRDEC	Fuel Reduction - Demand Side
EE-0520	HDT 42K BTU Environmental Control Unit	NSRDEC	Fuel Reduction - Demand Side
EE-0570	Energy Efficient Expedient Shelters with Non-woven Composite Insulation Liners	NSRDEC	Fuel Reduction - Demand Side
EE-0680	Desert Environment Sustainable Efficient Refrigeration Technology	NSRDEC	Fuel Reduction - Demand Side
EE-0700	Modular Appliances for Configurable Kitchens	NSRDEC	Fuel Reduction - Demand Side
EE-0720	Expeditionary TRICON Kitchen System Appliance, Fuel-Fired	NSRDEC	Fuel Reduction - Demand Side
EE-1050	V1.5 Shelter Liner	NSRDEC	Fuel Reduction - Demand Side
EE-1200	Deployable Metering and Monitoring System	ERDC	Fuel Reduction - Demand Side
EE-1220	Structural Insulated Panel Hut	ERDC	Fuel Reduction - Demand Side
EE-0030	HMMWV-Towable, Load-Following 100 kW Power Unit	CERDEC	Fuel Reduction - Supply Side
EE-0060	Single Common Powertrain Lubrication	TARDEC	Fuel Reduction - Supply Side
EE-0360	Energy Informed Operations-Central	CERDEC	Fuel Reduction - Supply Side
EE-1070	Man-Portable Genset for Power Generation for Expeditionary Small Unit Ops	CERDEC	Fuel Reduction - Supply Side
EE-1210	Hybrid Power Trailer	ERDC	Fuel Reduction - Supply Side
EE-0790	Modular Force Water Generation Storage & Analysis	TARDEC	Water Reduction
EE-0820	Real Time Inline Diagnostic Technology	TARDEC	Water Reduction
EE-0830	Rapid Identification and Quantification in Water - Pathogen Monitor	TARDEC	Water Reduction
EE-0850	Water Conservation Technology for Mobile Kitchens & Sanitation Centers	NSRDEC	Water Reduction
EE-0862	Graywater Reuse System - Forward Osmosis/Reverse Osmosis	TARDEC	Water Reduction
EE-1090	Efficient Water Reuse Technologies for COBs	ERDC	Water Reduction
EE-1160	Exploration of Water Demand Reduction Technologies - Shower Heads	NSRDEC	Water Reduction
EE-0920a	Solid Waste Destruction System - Altex Technology Corp	NSRDEC	Waste Reduction
EE-0940	Battalion Waste-to-Energy Converter	NSRDEC	Waste Reduction
EE-0980	Wastewater Treatment-Biological	TARDEC	Waste Reduction
EE-1110	Sustainable Technologies for Ration Packaging Systems	NSRDEC	Waste Reduction
EE-1140	Ration Packaging Reconfiguration	NSRDEC	Waste Reduction
EE-1230	Low-Cost TRICON Latrine	NSRDEC	Waste Reduction
EE-0685	Onsite Automatic Chiller for Individual Sustainment	NSRDEC	QoL
EE-0690	Containerized Ice Making Technologies	NSRDEC	QoL
	Containerized Ice Making System	PM E2S2	QoL

2.4 Research the Attributes in the Technology Portfolio Workbook

The EDVT researched the systems in the Technology Portfolio Workbook developed and maintained by the Technology Maturation and Integration Team (TMIT). The workbook contains a complete listing of all materiel solutions identified within the Army's R&D portfolio that could be potential contributors to FWW reductions. TMIT conducted several data calls related to system attributes and this information was documented by the TMIT in the workbook.

2.5 Compile Available Information

EDVT assessed the information available in the Technology Portfolio Workbook and found that much of the information was not current and would need to be updated. The best source for information on the attributes would be the individual Technology Providers.

2.6 Notify the Technology Providers of Information Requirements

The EDVT developed a worksheet and distributed it to the Technology Providers with a request for information. The worksheet looked similar to **Figure 1**.

(pick your technology from the dropdown list here)			
Function	**ID#**	**Attribute**	**Description, Justification, Comment, Supporting Information**
Readiness and Maturity	1.1	*TRL*	
Readiness and Maturity	1.2	*Standardization, Interoperability*	
Readiness and Maturity	1.3	*Tailorability, Modularity, Versatility, Scalability*	
Readiness and Maturity	1.4	*Net Ready*	
Human Systems Integration	2.1	*Manpower*	
Human Systems Integration	2.2	*Personnel Capabilities*	
Human Systems Integration	2.3	*HFE, Complexity*	
Human Systems Integration	2.4	*System Safety*	
Human Systems Integration	2.5	*Health Hazards*	
Human Systems Integration	2.6	*Training*	
Survivability	3	*Survivability*	
RAM-SS	4.1	*Reliability*	
RAM-SS	4.2	*Availability*	
RAM-SS	4.3	*Maintainability*	
RAM-SS	4.4	*Sustainability*	
RAM-SS	4.5	*Supportability*	
Force Projection	5.1	*Deployability*	
Force Projection	5.2	*Transportability*	
Impact of Footprint	6	*Impact of Footprint*	
Cost/Affordability	7	*Cost/Affordability*	
Soldier Feedback	8	*Soldier Feedback*	
Lessons Learned	9	*Lessons Learned*	

Figure 1: Attribute Worksheet

2.7 Gather Information from Technology Providers

The EDVT scheduled a series of exercises to meet with the Technology Providers, review their input, and make edits to the attribute worksheets. The EDVT prepared and distributed a plan (Harris, 2016) or a warning order to each RDEC for the respective exercise including the task, purpose, concept, agenda, and coordinating instructions. The agenda template was the same for each exercise:

- Introduction and presentation of the STA task (EDVT) (Harris, 2016).
- Review and edit of attribute worksheets (Technology Providers and EDVT).
- Review of action items (EDVT and CLT).

Four exercises were conducted, one with each RDEC, to complete the collection of attribute data. The complete sets of attribute data submitted by the Technology Providers and edited in the exercises are compiled in Annex B. Summary details for each exercise follow.

2.7.1 Exercise #1 NSRDEC, 25-26 October 2016, NSRDEC, MA

The first exercise was executed at NSRDEC in conjunction with the October 2016 SLB-STO-D Quarterly In-Progress Review #18. The STA exercise was conducted in the Grant Conference Room. This was the largest of the exercises in terms of participants and technologies reviewed. There were 32 attendees. In addition to personnel from the SLB-STO-D functional teams, the participants included the Technology Providers and representatives from Maneuver Support Battle Lab (MSBL), RDECOM, Army Test and Evaluation Command (ATEC), TARDEC, CERDEC, and the Armament RDEC (ARDEC).

The Technology Providers from NSRDEC presented attribute characteristics of 22 systems, including those listed in **Table 4**, as well as a few other technologies that were later deleted from this task. The CLT made edits in the attribute spreadsheets based on discussion during the exercise. After the exercise the EDVT distributed the updated spreadsheets for comment, as well as the detailed meeting notes.

2.7.2 Exercise #2 CERDEC, 31 January 2017, Aberdeen Proving Grounds, MD

The second exercise was conducted at CERDEC in the Power Division, Command, Power and Integration Directorate, Building 5100. There were 11 participants in this exercise including SLB-STO-D representatives from EDVT, CLT, MSBL, and the Technology Providers from CERDEC.

The EDVT gave an introduction to the STA task. There was discussion about how the attributes would be scored and assessed. It was during this exercise that the decision was made to develop a set of value curves for each technology focus area (see Section 2.8.2). The Technology Providers then presented attribute characteristics of four systems, including those listed in **Table 4**, as well as one other system that was later deleted from the assessment. Again, edits were made in the attribute spreadsheets based on discussion during the exercise. After the exercise the EDVT distributed the updated spreadsheets for comment, as well as the detailed meeting notes.

2.7.3 Exercise #3 TARDEC, 2 March 2017, Warren, MI

The third exercise was conducted at TARDEC in the conference room of Building 210. There were 10 participants in this exercise including SLB-STO-D representatives from EDVT, CLT, MSBL, and the Technology Providers from TARDEC.

Again, the EDVT gave an introduction to the STA task. The Technology Providers then presented and discussed attribute characteristics of six systems as indicated in **Table 4.** Attribute spreadsheet templates were projected in the conference room and annotated in real time by EDVT. It is TARDEC's goal for the water treatment systems to meet the reliability, availability, and maintainability (RAM) specifications found in the Tactical Water Purification System (TWPS) purchase description (Tank-automotive and Armaments Command (TACOM), 2006): (a) "The TWPS shall have a system hardware reliability of at least 180 hours hardware MTBEFF (mean time between essential function failures), and (b) "The TWPS shall have a MTTR (mean time to repair) no greater than 1 hour for all unscheduled maintenance demands and a MaxTTR no greater than 2 hours for 90% of all Essential Unscheduled Maintenance Demands..." This language was added to the attribute data. There was some discussion on manpower and personnel capabilities for operating and maintaining water treatment systems on base camps. The assembled experts recommended that a buddy team of Soldiers, MOS 92W (Water Treatment Specialist), could operate and maintain the water treatment and analysis systems on a 300-person base camp. After the exercise the EDVT distributed the scored spreadsheets for comment.

2.7.4 Exercise #4 ERDC/MSBL, 30 March 2017, Fort Leonard Wood, MO

The fourth and final exercise was conducted in two parts at the Maneuver Support Center of Excellence (MSCoE) at Fort Leonard Wood, MO. The first part was conducted in the camp administration building at the CBITEC. The Technology Providers from ERDC were invited to present and review the attributes of their respective systems in the SLB-STO-D portfolio. There were nine participants for the exercise including SLB-STO-D representatives from EDVT and CLT, the MSBL, TCM Maneuver Support, and one Technology Provider from ERDC. Only the Efficient Water Reuse Technologies for Contingency Operating Bases was available for this exercise. But as a bonus, the system was actually set up in the camp and the exercise participants were able to view the system and receive an in depth briefing from the Technology Provider.

The second part of Exercise #4 was conducted in the conference room of the library at MSCoE Headquarters. The purpose of this event was to develop value curves (see Section 2.8.2) for the attributes and then weight the attribute categories (see Section 2.8.3). The SLB-STO-D convened a panel of base camp SMEs to assist with this task. Analysts from the MSBL guided three SMEs (**Table 5**) in a step-by-step process to develop the value curves and weights.

Table 5: Base Camp SMEs

Subject Matter Expert (name withheld)	Military Service	Current Duty Description	Short Description of Experience (with military operations on extra-small and small base camps)
1	Retired Colonel, 1982-2012	System Engineer at Booz Allen Hamilton in Detroit, Michigan. Supports the Product Director for Contingency Base Infrastructure (PD CBI).	Served one year at Kandahar Airfield and traveled to many small and extra-small base camps. Participated in the design and building of base camps. Currently provides military operations expertise and systems engineering support to PD CBI.
2	Retired Sergeant First Class (SFC), 1989-2011	STO-D support at NSRDEC.	As a career Soldier and leader, was involved with sustainability of deployed US forces. At the National Training Center, responsible for the monitoring and teaching the battalion tactical operations centers. Experiences cover the full spectrum of staff operations at the battalion and brigade levels.
3	Retired SFC, 1990-2014 (1990-2001 US Marine Corps; 2001-2014 US Army)	Senior Policy Analyst. Writes requirements documents and strategies. Conducts gap analysis and doctrine, organization, training, material, leadership, personnel, facilities (DOTMLPF) analysis.	Served as a force protection/base defense Non-Commissioned Officer (NCO) in Tikrit, Iraq in 2003. From 2007-2009, served at an entry control point at Victory Base Camp in Baghdad, Iraq.

2.8 Evaluate the Information

This was the most complicated step of the assessment and involved a number of players, including the MSBL, a panel of base camp SMEs, and the SLB-STO-D Data Authentication Group (DAG). In this step the EDVT and the MSBL employed a Multi-Attribute Decision Making process to quantify the technology attributes that show operational value to the ultimate user of the technology.

2.8.1 Develop Metrics

First, the EDVT developed a set of metrics, on a whole-number scale from 1 to 7, for each attribute area (see again **Table 3** above). The metric definitions are shown below in **Table 6**.

Table 6: Attribute Metrics and Definitions

Attribute Category	Metric
Readiness and Maturity	7 = perfection; this system is ready now to be fully integrated into an operational base camp with full user acceptance of the attributes 6 = meets most of the attributes and, with sufficient funding, could be on a developmental path to satisfy the attributes according to schedule 5 = meets most of the attributes, some required design changes have been identified that would make the system fully acceptable 4 = meets many of the attributes, more evaluation is required to fully assess 3 = meets some of the attributes, but would require significant R&D to be acceptable 2 = meets some of the attributes, user would have to change or relax requirements for the system to ever be acceptable 1 = failure; not ready, and likely never will be, to meet the attributes
Human Systems Integration	7 = perfection; this system is ready now to be fully integrated into an operational base camp with full user acceptance of the attributes 6 = meets most of the attributes and, with sufficient funding, could be on a developmental path to satisfy the attributes according to schedule 5 = meets most of the attributes, some required design changes have been identified that would make the system fully acceptable 4 = meets many of the attributes, more evaluation is required to fully assess 3 = meets some of the attributes, but would require significant R&D to be acceptable 2 = meets some of the attributes, user would have to change or relax requirements for the system to ever be acceptable 1 = failure; not ready, and likely never will be, to meet the attributes
Survivability	7 = perfection; this system is fully survivable 6 = system is "military hardened" with redundant modes and/or modes for graceful degradation 5 = system is "military hardened" but could fail under extreme conditions 4 = system has some "military hardening", but would require further R&D to optimize survivability 3 = survivable under usual operations, but could fail if a damaging event occurs 2 = survivable under usual operations, but will fail readily if a damaging event occurs 1 = failure; not survivable, even under usual operations
RAM-SS	7 = perfection; this system is ready now to be fully integrated into an operational base camp with full user acceptance of the attributes 6 = meets most of the attributes and, with sufficient funding, could be on a developmental path to satisfy the attributes according to schedule 5 = meets most of the attributes, some required design changes have been identified that would make the system fully acceptable 4 = meets many of the attributes, more evaluation is required to fully assess 3 = meets some of the attributes, but would require significant R&D to be acceptable 2 = meets some of the attributes, user would have to change or relax requirements for the system to ever be acceptable 1 = failure; not ready, and likely never will be, to meet the attributes
Force Projection	7 = perfection; this system is easily deployable and transportable without extra burden on the unit 6 = system is easily deployable and transportable, but requires a(n) extra asset(s), such as a pallet, container, truck, etc. 5 = system is deployable and transportable, but requires coordination of special requirements from higher Headquarters or other units, such as heavy lift 4 = system is deployable and transportable, but requires additional planes or ships to get to theater 3 = system is deployable and transportable, but requires extra assets and coordination of special requirements, such as an asset that is located far away or has a very long lead time to acquire 2 = requires unusual preparation or special assets to deploy and transport 1 = failure; not ready, and likely never will be, to meet the attributes

2.8.2 Develop Value Curves

These metrics and their definitions were presented to a panel of base camp SMEs. The SMEs were polled to determine at what metric level a certain attribute category would have value, or be acceptable to a user, on a scale of 0 to 100 (**Table 7**). In this manner value curves were developed for each attribute category for each technology focus area. A sample value curve is shown in **Figure 2**. The complete set of 25 resulting value curves is shown in Annex C.

Table 7: Attribute Value Scale

Value To You	
100	Maximum Value
90	Very High Value
80	High Value
70	
60	
50	Worthwhile
40	
30	
20	Low Value
10	Very Low Value
0	Worthless / No Value

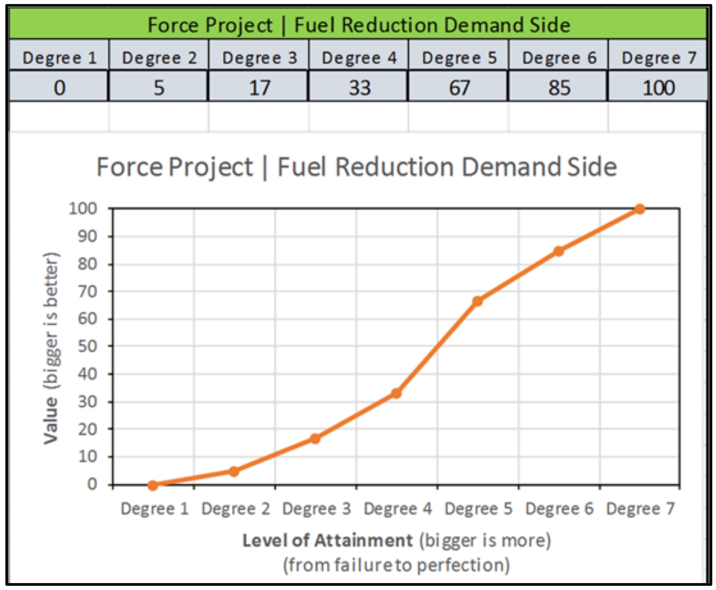

Figure 2: Sample Value Curve

2.8.3 Weight the Attribute Categories

The SMEs also weighted the attribute categories. The SMEs were polled to determine if an attribute category is…

- much more important (score 5.00)
- more important (score 3.00)
- same importance (score 1.00)
- less important (score 0.33)
- much less important (score 0.20)

…than another attribute category in a pairwise comparison. These comparisons were made for the attribute categories for each technology focus area. The resulting weighted values of the attribute categories for each technology focus area are shown in **Table 8**.

2.8.4 Score the Attributes

The EDVT reviewed each attribute worksheet submission and, applying the metrics definitions, assigned each attribute category a preliminary score of 1-7. The EDVT also provided comments to justify each score.

Table 8: Weighted Attribute Values

Fuel Reduction Demand Side

ROW -vs- COLUMN	Ready	HSI	Surviv	RAM-SS	Force	Total	%		Rank
Ready	X	0.89	1.34	1.11	3.33	6.68	24%	Ready	2
HSI	1.13	X	3.67	1.67	3.33	9.79	35%	HSI	1
Surviv	0.74	0.27	X	0.61	1.44	3.07	11%	Surviv	4
RAM-SS	0.90	0.60	1.64	X	3.33	6.47	23%	RAM-SS	3
Force	0.30	0.30	0.69	0.30	X	1.59	6%	Force	5
						27.60	100%		

Fuel Reduction Supply Side

ROW -vs- COLUMN	Ready	HSI	Surviv	RAM-SS	Force	Total	%		Rank
Ready	X	0.89	1.34	2.07	3.33	7.63	26%	Ready	2
HSI	1.13	X	3.67	1.67	3.33	9.79	34%	HSI	1
Surviv	0.74	0.27	X	0.39	1.44	2.85	10%	Surviv	4
RAM-SS	0.48	0.60	2.57	X	3.33	6.99	24%	RAM-SS	3
Force	0.30	0.30	0.69	0.30	X	1.59	6%	Force	5
						28.86	100%		

Water Reduction

ROW -vs- COLUMN	Ready	HSI	Surviv	RAM-SS	Force	Total	%		Rank
Ready	X	1.11	1.44	1.73	3.33	7.62	29%	Ready	2
HSI	0.90	X	2.33	1.67	3.33	8.23	31%	HSI	1
Surviv	0.69	0.43	X	1.11	1.67	3.90	15%	Surviv	4
RAM-SS	0.58	0.60	0.90	X	3.33	5.41	20%	RAM-SS	3
Force	0.30	0.30	0.60	0.30	X	1.50	6%	Force	5
						26.66	100%		

Waste Reduction

ROW -vs- COLUMN	Ready	HSI	Surviv	RAM-SS	Force	Total	%		Rank
Ready	X	2.00	1.34	3.00	3.33	9.68	33%	Ready	1
HSI	0.50	X	3.00	1.67	3.33	8.50	29%	HSI	2
Surviv	0.74	0.33	X	0.39	1.44	2.91	10%	Surviv	4
RAM-SS	0.33	0.60	2.57	X	3.33	6.84	23%	RAM-SS	3
Force	0.30	0.30	0.69	0.30	X	1.59	5%	Force	5
						29.52	100%		

Quality of Life

ROW -vs- COLUMN	Ready	HSI	Surviv	RAM-SS	Force	Total	%		Rank
Ready	X	1.00	2.90	2.07	3.33	9.30	32%	Ready	1
HSI	1.00	X	3.00	1.67	3.33	9.00	31%	HSI	2
Surviv	0.34	0.33	X	1.94	1.44	4.07	14%	Surviv	4
RAM-SS	0.48	0.60	0.51	X	3.33	4.93	17%	RAM-SS	3
Force	0.30	0.30	0.69	0.30	X	1.59	6%	Force	5
						28.89	100%		

2.8.5 Authenticate the Attribute Scores

The CLT convened the SLB-STO-D DAG to review and authenticate the scores. This meeting was held immediately prior to Quarterly In-Progress Review #20 in April 2017. The DAG consisted of one voting member from each functional team – CLT, EDVT, SEIT, MSAT, TMIT, and the Requirements Integration Team (RIT) – plus the DAG Chair. The DAG reviewed all data sheets, discussed, and then updated scores as required. (NOTE: The DAG also scored the attributes of the Onsite Automatic Chiller for Individual Sustainment based on experience at demonstration, even though attribute data were not yet available.)

2.8.6 Analyze the Attribute Scores

The final task in Step #8 was to apply the weighted values to the authenticated scores and "do the math". The MSBL executed this task. Raw scores and results for each technology are shown below in Chapter 3.

2.9 Identify Missing or Inadequate Information

Even after all previous steps neared completion, there were still many gaps in the data. The EDVT continued research to fill as many data gaps as possible.

2.10 Repeat the Process Until Complete

This report represents all the available or known data for the system attributes at the close of this task.

3. SELECTED TECHNOLOGY ASSESSMENT

The results of the STA are documented in this chapter. The selected technologies are grouped by technology thrust area — Fuel Reduction-Demand Side, Fuel Reduction-Supply Side, Water Reduction, Waste Reduction, and Quality of Life — to align with the results of the MSAT analysis. This chapter serves as a catalog of technologies with a system description for each technology followed by the results of the assessment as described above in the Methodology chapter. The results are first shown with a bar graph, as seen in the example below in **Figure 3**.

Figure 3: Sample of Results Bar Graph

The percent score for each attribute area is calculated from the raw attribute score (1 through 7) plotted on the value curve for that attribute in that technology thrust area. Following the bar graph for each system is a comment for each attribute area explaining or justifying the score. The single value in the upper-left corner of the diagram is the overall weighted score of the combined attributes.

> **IMPORTANT NOTE**: It is imperative that the overall weighted score be considered in the context of the SLB-STO-D project and this assessment. All technologies included in this report have passed two down-select processes – first, being selected for the SLB-STO-D portfolio and consideration for analysis; second, being included in the Integrated Solution Sets as a contributor to meeting the challenge of reducing FWW on contingency base camps. The score should not be considered as a passing or failing grade. Instead, the score is an indication of the system's progress along its acquisition life cycle. Systems with higher scores may be ready now to contribute to more efficient base camps. Systems with lower scores may need more time and funding to be fielded, but show significant promise through demonstration and analysis.

3.1 Fuel Reduction – Demand Side

Table 9 contains a list of the technologies examined for potential fuel reduction on the demand side.

Table 9: Fuel Reduction-Demand Side - Technologies

ID	Technology/Component	Lab/ RDEC
EE-0290	PowerShade Cost Reduction (PSHADE)	NSRDEC
EE-0300	Self-Powered Solar Water Heater (SPSWH)	NSRDEC
EE-0520	HDT 42K BTU Environmental Control Unit (HDT-42K)	NSRDEC
EE-0570	Energy Efficient Expedient Shelters with Non-woven Composite Insulation Liners (LINER)	NSRDEC
EE-0680	Desert Environment Sustainable Efficient Refrigeration Technology (DESERT)	NSRDEC
EE-0700	Modular Appliances for Configurable Kitchens (MACK)	NSRDEC
EE-0720	Expeditionary TRICON Kitchen System Appliance Integration (FF-ETK)	NSRDEC
EE-1050	V1.5 Liner (V1.5)	NSRDEC
EE-1200	Deployable Metering and Monitoring System (DMMS)	ERDC
EE-1220	Structural Insulated Panel Hut (SIP-Hut)	ERDC

3.1.1 PowerShade Cost Reduction (PSHADE)

3.1.1.1 System Description

The PSHADE (**Figure 4**) is a fabric structure with built-in photovoltaic (PV) array that is designed to shade and provide power to tents (such as TEMPER (Tent, Extendable, Modular, Personnel) air-supported or framed shelters), rigid-wall shelters, vehicles, etc.

Figure 4: PSHADE over a TEMPER Air-Supported Tent

The congressionally-funded PSHADE program intends to reduce costs and improve PV component parts by focusing on extending durability of the base textile materials, reducing manufacturing cost of components via optimized design and manufacturing processes, and increasing the efficiency of the Balance of System (BOS) by implementation of grid-tie capability and high efficiency power electronics. These combined efforts hold promise to provide a higher electrical generating capability at a lower weight and cost, offering a more attractive alternative or supplement to traditional fuel-fired electrical generators.

Other goals of the effort are to:

- Reduce initial procurement costs by 20% (Threshold (T)) to 30% (Objective (O)) for a given PV generation capability
- Increase peak kilowatt (kW) output of a given size PSHADE by 10% (T) to 20% (O)
- Increase lifespan from a 3-year specification to 10 years
- Reduce deployment effort required for erection of the system by reduction of weight of structural components

Technical Point of Contact (POC): Steven Tucker, NSRDEC, steven.r.tucker10.civ@mail.mil, 508-233-6962.

3.1.1.2 Technology Assessment

Figure 5 contains the Technology Assessment scoring information for the PSHADE.

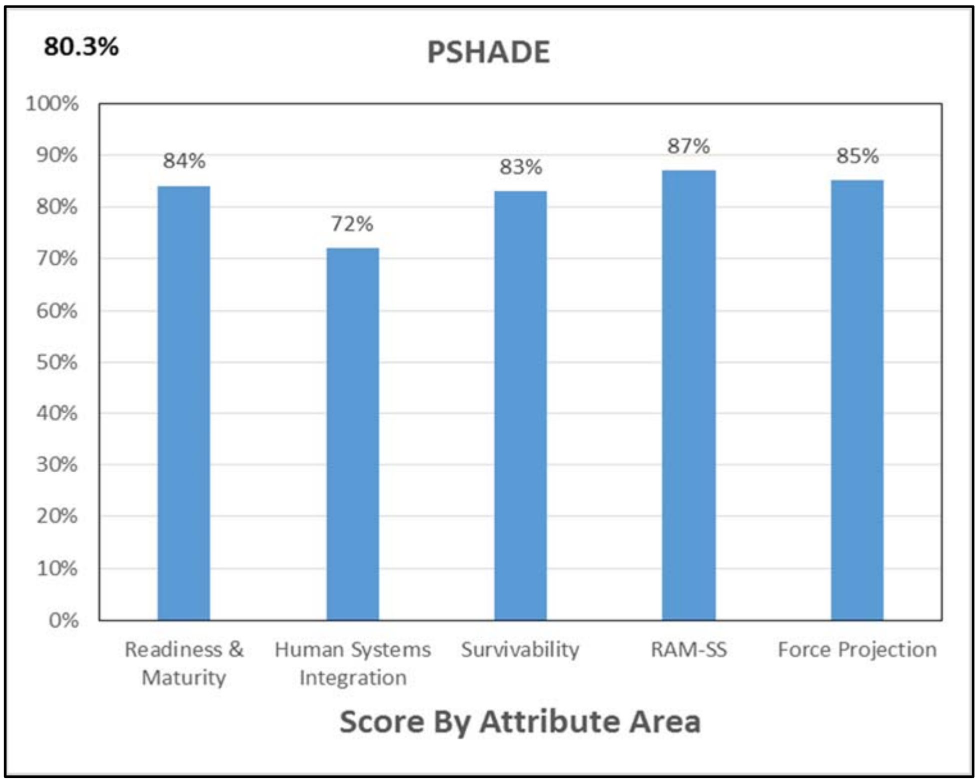

Figure 5: Technology Assessment Graph for PSHADE

Readiness and Maturity: The PSHADE is mature and ready for operations. There were only minor concerns at demonstration regarding operation of the grid-tie connections. More evaluation is recommended for this feature.

Human Systems Integration: The PSHADE is only a little more manpower intensive than a normal shade or camouflage system. Some effort will be required, especially in dusty environments, to keep the solar panels free of debris.

Survivability: The PSHADE will be susceptible to high winds and snow. While the effects of CBRN decontamination of the system are not known, it is possible that the shade could increase the survivability of the structure underneath the shade in such an environment.
RAM-SS: The PSHADE system is likely reliable and maintainable. It is unknown at this point the likelihood of occurrence of short circuits due to rainstorms and flapping of panels and cables, etc. Another concern will be keeping the panels clear of debris, especially dust, pollen, leaves, snow, ice, etc. The system would not be available during periods of significant snow and ice.

Force Projection: The PSHADE is readily deployable and transportable. It seems to require only a little more packing and set up space than some other shades or camouflage systems.

3.1.2 Self-Powered Solar Water Heater (SPSWH)

3.1.2.1 System Description

The SPSWH **(Figure 6)** technology project will develop alternative energy technology to enhance the capability to reduce fuel required for heating and pumping water by concentrating solar energy to heat water and generate electric power for a pump.

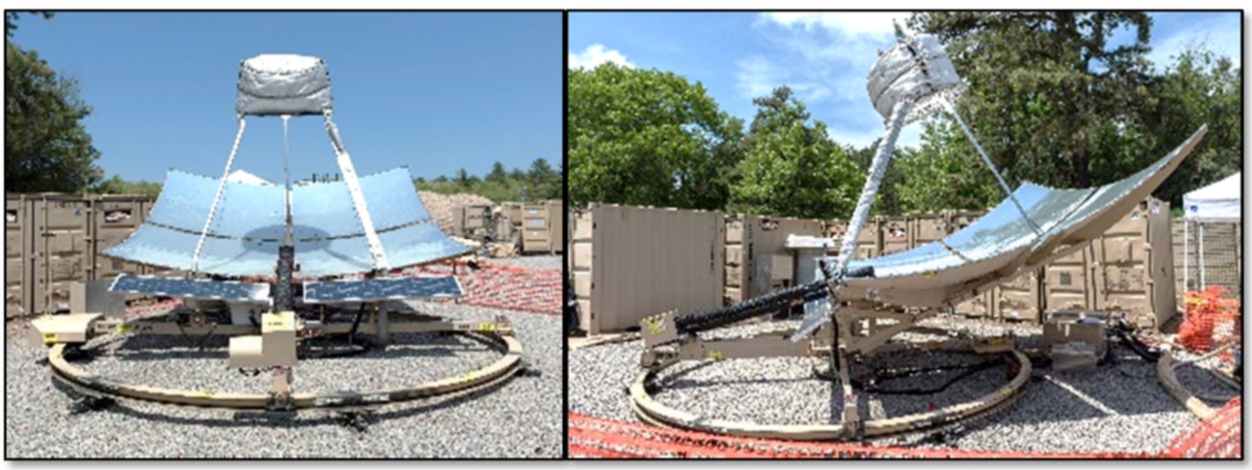

Figure 6: Self-Powered Solar Water Heater

The SPSWH demonstrated at the BCIL was comprised of and supplemented by the following components and equipment:

- SPSWH system, including water pump and battery pack (**Figure 7**)
- Pressure regulator (**Figure 8**)
- AWH-400 fuel-powered water heater (**Figure 9**)
- Two three-way valves (**Figure 10**)

Figure 7: SPSWH Including Water Pump and Battery Pack

Figure 8: Pressure Regulator

Figure 9: Army Water Heater-400

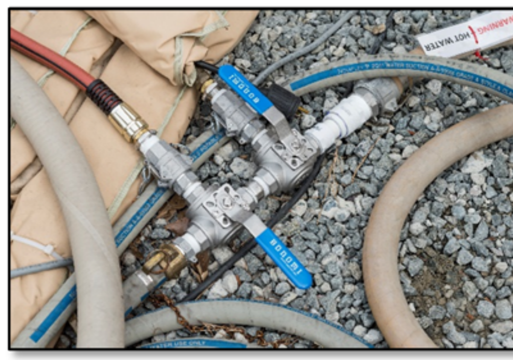

Figure 10: Two Three-way Valves

The SPSWH technology demonstrated the following capabilities and products:

- Four modular, man-portable components (147 lb) with thermal/electricity collectors
- Generate 200 W of power for a 5-gpm (gallons per minute) pump
- Provide an instant hot water source for up to 240 gal per day
- Transport and store in TRICON (triple container, i.e., one-third size standard) shipping container
- High reliability (mostly solid state)
- Supplements/offsets M80/AWH-400 water heater assets

Demonstration of the above capabilities and products are intended to deliver:

- Hot water to support field kitchen and sanitation center operations; may also support showers and latrines with the ability to couple SPSWH units for additional hot water capacity
- 250 kBTU (British Thermal Units) per day per SPSWH. With the target objective of packaging three SPSWH units per TRICON, a total 750 kBTU per day of hot water could be generated.

- Low maintenance, high reliability; requires four personnel for initial setup in 4 h

The SPSWH is currently at TRL 4 with a full-scale Phase II Small Business Innovation Research (SBIR) Enhancement prototype (**Figure 11**) to be demonstrated to the Product Manager for Force Sustainment Systems (PdM-FSS) for consideration and transition to target application(s).

Technical POC: Peter Lavigne, NSRDEC, peter.g.lavigne.civ@mail.mil, 508-233-4939.

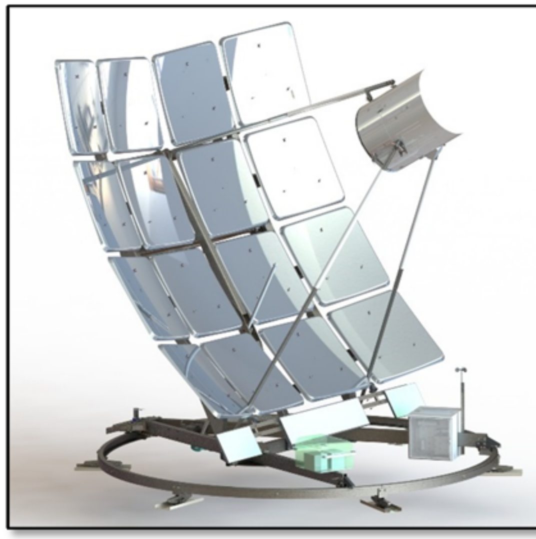

Figure 11: SPSWH Helia Enhancement Prototype II

3.1.2.2 Technology Assessment

Figure 12 contains the Technology Assessment scoring information for the SPSWH.

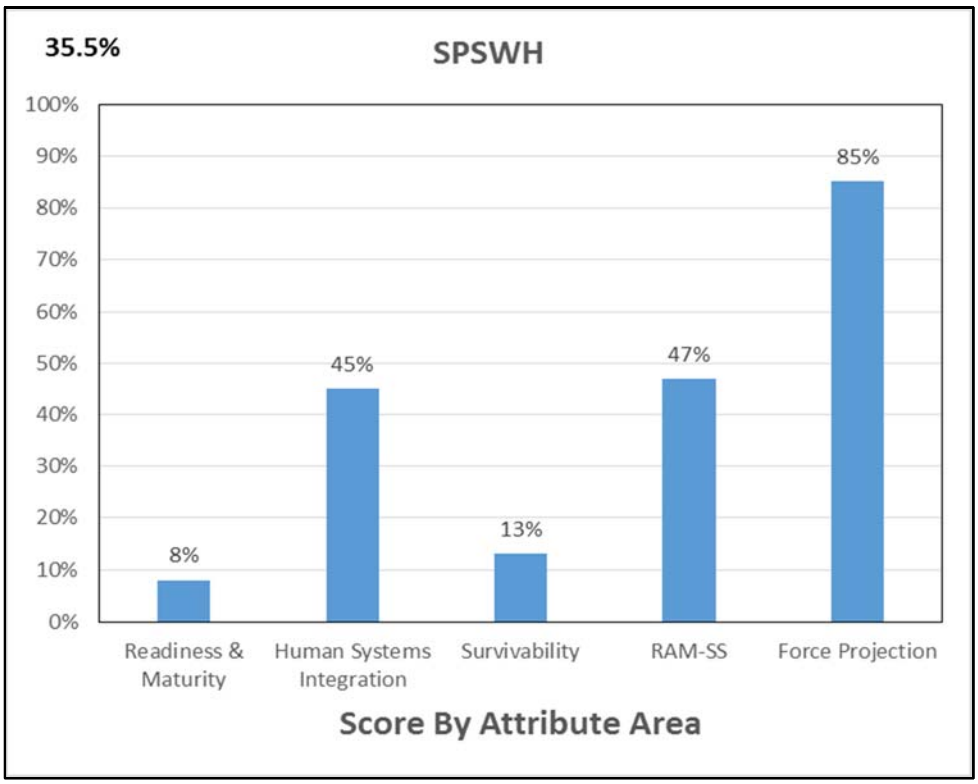

Figure 12: Technology Assessment Graph for the SPSWH

Readiness and Maturity: As demonstrated, this system is still rather immature. However, enhancements are programmed for the next phase of development.

Human Systems Integration: This system required a significant amount of attention during operation to make sure it was tracking the sun. Also, there are a number of safety hazards to be mitigated.

Survivability: As demonstrated, this system has little to no military hardening yet.

RAM-SS: Unknown at this point how reliable the system will be. More evaluation is recommended.

Force Projection: This system packs away in TRICON containers, but is additional equipment and the unit must plan additional transportation assets. It could take several units to make a difference in the camp's fuel requirement, so a significant footprint must be dedicated.

3.1.3 HDT 42K BTU Environmental Control Unit (HDT-42K)

3.1.3.1 System Description

The HDT-42K (**Figure 13**) is a commercially available variable speed 42K BTU Environmental Control Unit (ECU) that provides heating, cooling, and dehumidification for expeditionary shelters, hardwall shelters, vans, ISO (International Organization for Standardization) containers, etc.

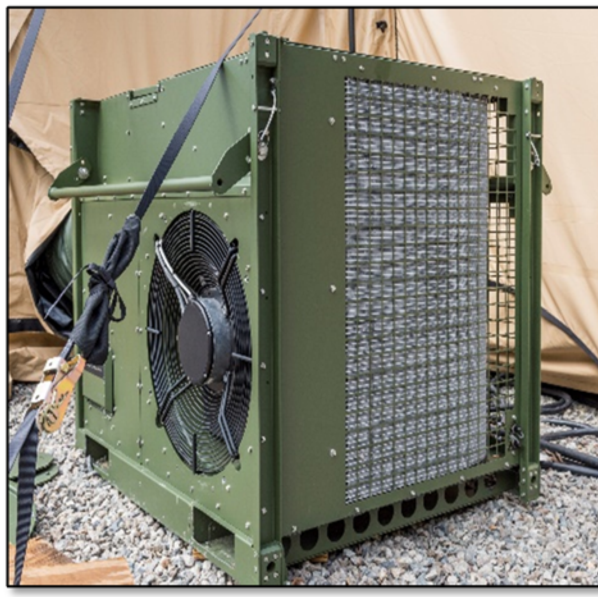

Figure 13: HDT-42K ECU

The key features of the HDT-42K are:

- Built-in compartments to house insulated flexible ducts, electrical power cable, and remote control
- Transport or storage covers for all openings for supply and return air
- Lifting and tie-down provisions
- Built-in electrical phase monitor
- Skid-mounted with forklift pockets for ease of movement and set-up
- Bolted frame for ease of repair (all frame members are available as spare parts)
- Duct connection for nuclear, biological, and chemical (NBC) filtration equipment

The HDT-42K benefits are:

- Increased energy efficiency by using variable speed motors that adjust to environmental conditions and comfort setting
- Lower maintenance and replacement costs

The HDT-42K is a commercially available item.

3.1.3.2 Technology Assessment

Figure 14 contains the Technology Assessment scoring information for the HDT-42K.

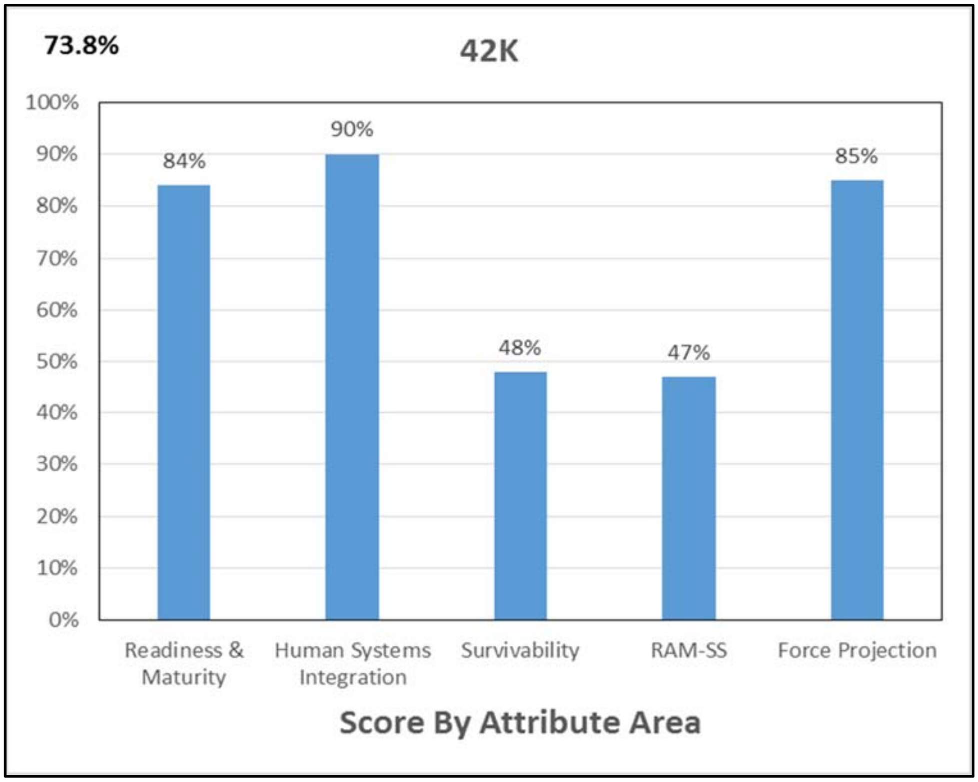

Figure 14: Technology Assessment Graph for the HDT-42K

Readiness and Maturity: Only a few systems have been manufactured, but they performed well during demonstration.

Human Systems Integration: Reduced size compared to baseline system makes this ECU easier to handle and is quieter during operation.

Survivability: This system will require additional testing under various conditions.

RAM-SS: The durability metrics are unknown. The supportability and sustainability attributes would be very similar to, or perhaps better than, the currently fielded system due to the variable speed motor.

Force Projection: This system is smaller in size than the F100 ECU, so there are no force projection issues to note.

3.1.4 Energy Efficient Expedient Shelters with Non-woven Composite Insulation Liners (LINER)

3.1.4.1 System Description

The LINER (**Figure 15**, shown installed) is an Army Manufacturing Technology project that endeavors to develop an improved manufacturing process for non-woven, composite insulation

liners to be used for energy conservation in expedient soft wall shelters. Manufacturing improvements will increase thermal performance and likelihood of transition into a fielded shelter while decreasing product cost and weight.

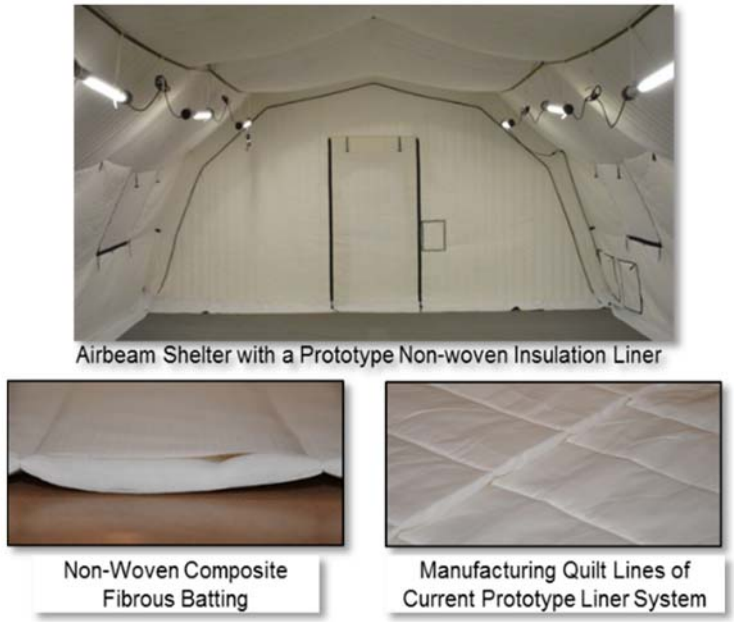

Figure 15: LINER

Enhanced non-woven composite tent liners will provide improved thermal performance in highly-agile soft wall shelters.

Other important features of the LINER project are:

- Soldiers will experience a higher quality of life due to better climate control and enhanced ease of insulated shelter set-up
- Demonstration of enhanced manufacturing capability through two full-scale prototype tent liners – one for a standard 32 ft TEMPER and one for an air-supported tent
- Reduction of the shelter's infrared signature
- Better maintainability of habitable temperature conditions within Army-deployed shelter systems

The LINER is currently at TRL 9 and has been transitioned to PdM-FSS under Expeditionary Force Provider.

Technical POC: Elizabeth D. Swisher, NSRDEC, elizabeth.d.swisher.civ@mail.mil, 508-233-5457.

3.1.4.2 Technology Assessment

Figure 16 contains the Technology Assessment scoring information for the LINER.

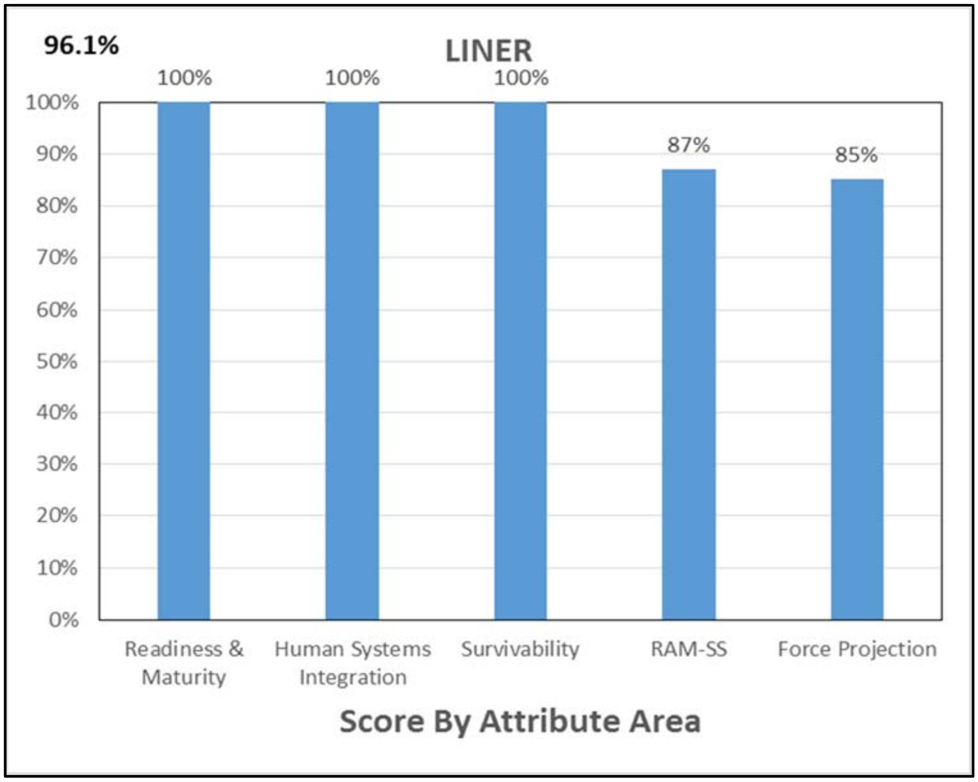

Figure 16: Technology Assessment Graph for the LINER

Readiness and Maturity: This item is fielded.

Human Systems Integration: No issues identified.

Survivability: This liner is porous and less resistant to POL (petroleum, oil, and lubricants) and mildew.

RAM-SS: Some improvements could be made to improve its durability.

Force Projection: This liner is bulkier than the original liner. Packout is larger, but still occupies the allotted space in the shipping container.

3.1.5 Desert Environment Sustainable Efficient Refrigeration Technology (DESERT)

3.1.5.1 System Description

The DESERT (**Figure 17**) project will demonstrate a High-Efficiency Refrigeration Unit (HERU). The HERU is intended as a plug-and-play replacement to the cooling systems in existing Army 20 ft cold-storage containers, and utilizes the existing Multi-Temperature Refrigerated Container System (MTRCS) as the demonstration platform. Compared to legacy systems, the HERU is twice as efficient, twice as effective, and operates in extremely hot environments. Fuel savings are achieved solely through the higher efficiency, while additional savings are possible via the ability to interface with renewable energy sources such as solar

photovoltaics. It includes an on-board generator set for backup power or for operation while mobile. This demonstration includes a DESERT Power 2 (DP2) solar array (**Figure 18**), which is a standard Solar System I shade modified by the inclusion of 2 kW of flexible solar panels. The array provides electricity simultaneously with conventional inputs, thus offsetting fuel use.

Figure 17: DESERT

Important characteristics of the HERU are:

- Even without solar assist, the reduced power requirement can save energy
- Max power draw of 8 kW under demanding conditions, and no surge = smaller gensets
- Doubled mean-time between failures, from 500 to 1000 hours = greater reliability
- High temperature capability to 135 °F ambient = operation in hot theaters
- Greater reliability, hot climate compatibility, and cooling capacity = less food loss
- 16% lower initial procurement cost = lower production cost and lower replacement cost
- No tradeoffs. This technology will meet and exceed all existing operational requirements
- The computer diagnostics will ease maintenance

Figure 18: DP2 Solar Array

The HERU is approaching TRL 7 and transition to PdM-FSS is pending.

Technical POC: Alexander J. Schmidt, NSRDEC, alexander.j.schmidt4.civ@mail.mil, 508-233-4244.

3.1.5.2 Technology Assessment

Figure 19 contains the Technology Assessment scoring information for the DESERT.

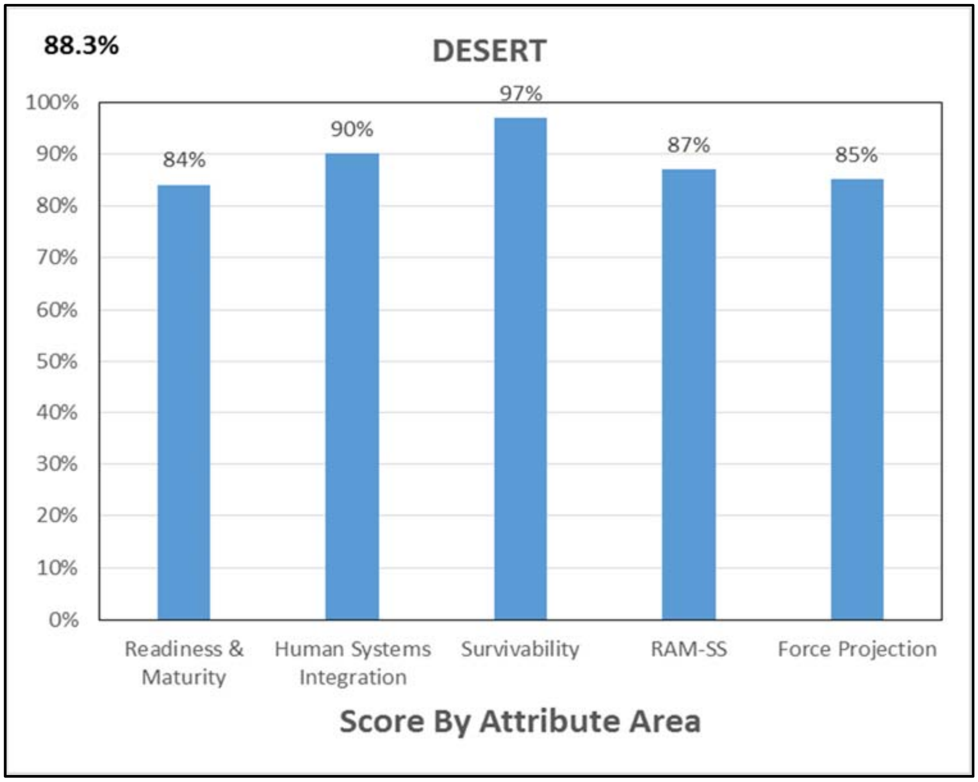

Figure 19: Technology Assessment Graph for the DESERT

Readiness and Maturity: There were a number of issues identified at CBITEC during the demonstration. These issues were mostly resolved with updates to the software configuration.

Human Systems Integration: There were no HSI issues identified at CBITEC during the demonstration. This system will be similar to the fielded unit for HSI.

Survivability: This system has incorporated the ability to accept other sources of power, plus it includes a backup generator for its own power.

RAM-SS: This system is expected to be twice as reliable as the system it is intended to replace.

Force Projection: There is no additional force projection burden on the unit to adopt this equipment.

3.1.6 Modular Appliances for Configurable Kitchens (MACK)

3.1.6.1 System Description

The MACK is a suite of modular fuel-fired kitchen appliances (**Figure 20**) that can be configured for use across all Army field feeding platforms. The modular appliances are designed to replace current fuel-fired appliances which are inefficient, loud, expensive, and exhaust heat and combustion products into the kitchen workspace.

Key features of the MACK are:

Figure 20: Modular Appliances for Configurable Kitchens

- Far quieter and easier to use than current appliances, and does not vent heat and exhaust into cooking area
- Standardized design concept that minimizes the number of inventoried parts and reduces the total number of National Stock Number (NSN) parts
- Standard suite across all mobile kitchen platforms simplifies training. All kitchens use common components that can scale to outfit kitchens with different capacities
- Modular nature of components enables easy disassembly into man-portable pieces for integration into different platforms or buildings
- Compared to current Jet Propulsion fuel type 8 (JP-8) appliances, fuel is reduced across all appliance types
- Typical power requirements per appliance are reduced from approximately 90 W for the Modern Burner Unit to 50 W for the Joint Inter-service Field Feeding burner

The MACK appliances are currently at TRL 6 and transition to PdM-FSS is pending.

Technical POC: Joseph J. Quigley, joseph.j.quigley6.civ@mail.mil, 508-233-5860.

3.1.6.2 Technology Assessment

Figure 21 contains the Technology Assessment scoring information for the MACK.

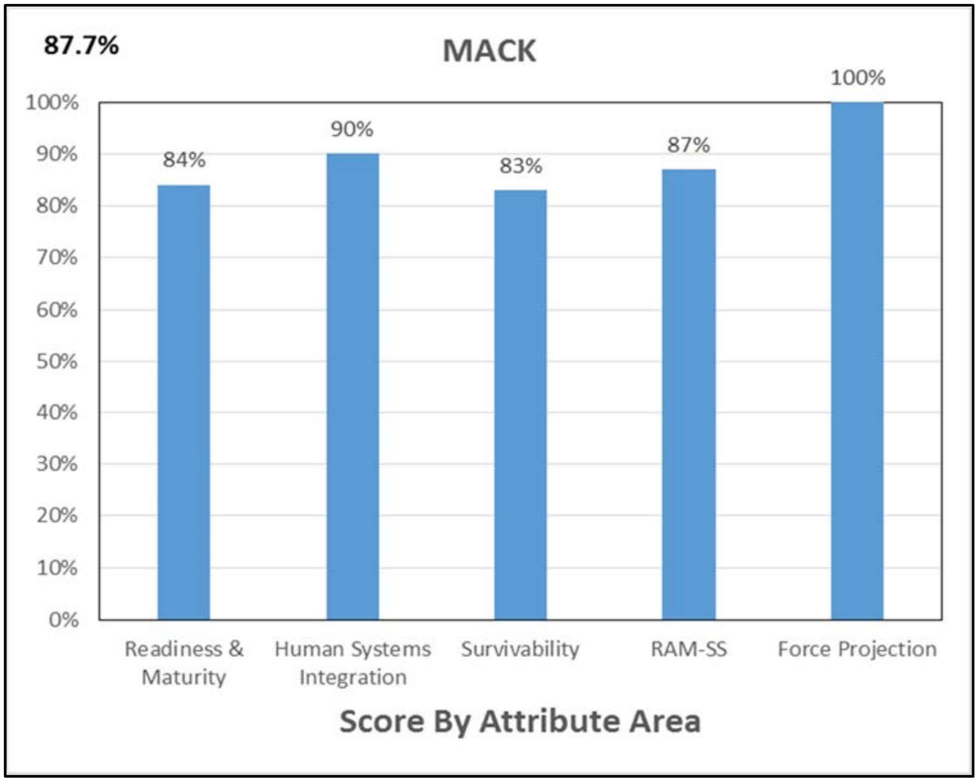

Figure 21: Technology Assessment Graph for the MACK

Readiness and Maturity: This system performed well at the demonstration with very few issues identified.

Human Systems Integration: This system was very well received by the Soldiers during the demonstration.

Survivability: Commonality of parts does enable some redundant modes.

RAM-SS: System should be as supportable as legacy kitchen systems.

Force Projection: Same as current system.

3.1.7 Expeditionary TRICON Kitchen System Appliance Integration (FF-ETK)

3.1.7.1 System Description

The FF-ETK (**Figure 22**) appliance integration is a testing and demonstration project to evaluate new energy-efficient, fuel-fired kitchen appliances. The primary purpose of the project is to measure and compare the amount of fuel saved by using fuel-fired appliances compared to electric appliances.

The FF-ETK offers the following benefits:

Figure 22: Expeditionary TRICON Kitchen System Appliance Integration

- Reduce the energy consumption of the Expeditionary TRICON Kitchen system used for cooking by 50%-60%
- Electrical power required for each cooking appliance will typically be 60 W or less; therefore, the total electrical input for cooking will be reduced to less than 1.0 kW. This is a reduction of over 95% as compared to electrical appliances
- Leverage Army's modular appliance initiative for maneuver field kitchens

The FF-ETK is currently at TRL 6 and scheduled to transition to PdM-FSS in FY17 at TRL 7.

Technical POC: Joseph Quigley, NSRDEC, joseph.j.quigley6.civ@mail.mil, 508-233-5860.

3.1.7.2 Technology Assessment

Figure 23 contains the Technology Assessment scoring information for the FF-ETK.

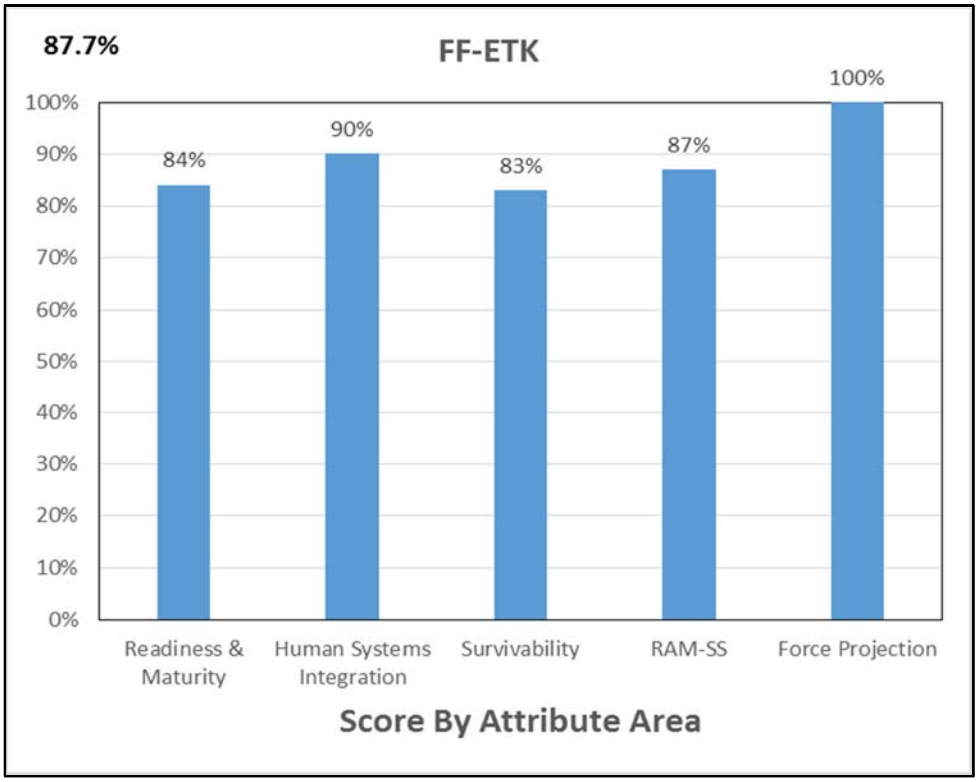

Figure 23: Technology Assessment Graph for the FF-ETK

Readiness and Maturity: This system performed well at the demonstration with very few issues identified.

Human Systems Integration: A field kitchen must rate very high for HSI, and those that are fielded generally do. This technology is a drop-in replacement for appliances, and does not negatively impact the HSI of the kitchen as a whole.

Survivability: Commonality of parts does enable some redundant modes.

RAM-SS: System should be as supportable as legacy kitchen systems.

Force Projection: Same as current system.

3.1.8 V1.5 Shelter Liner (V1.5)

3.1.8.1 System Description

The V1.5 Shelter Liner (**Figure 24**) is a variant of the original LINER as described in Section 3.1.4. The V1.5 Shelter Liner features improved insulation, with radiant barrier, built-in plenum to form an "attic" in the shelter, and built-in LED (light-emitting diode) lights.

Figure 24: V1.5 Shelter Liner

Technical POC: Elizabeth D. Swisher, NSRDEC, elizabeth.d.swisher.civ@mail.mil, 508-233-5457.

3.1.8.2 Technology Assessment

Figure 25 contains the Technology Assessment scoring information for the V1.5.

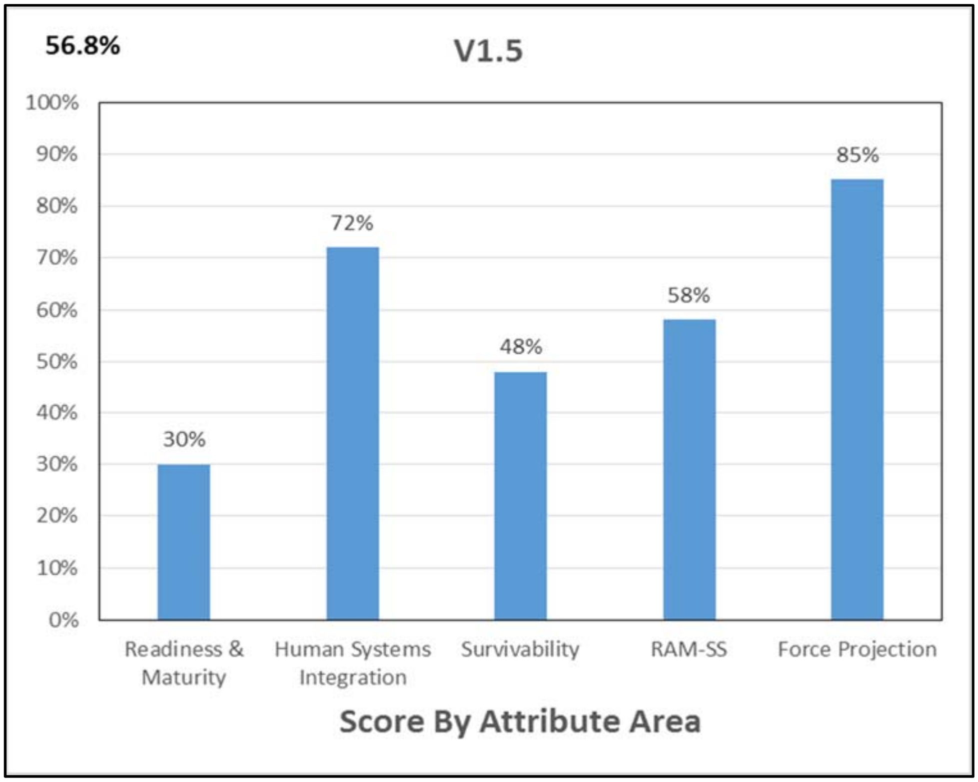

Figure 25: Technology Assessment Graph for the V1.5

Readiness and Maturity: Currently only ready for one shelter size.

Human Systems Integration: A few HSI issues identified, mostly during setup.

Survivability: The liner received some damage during pack-up and installation, i.e., during transport. No degradation observed during operation.

RAM-SS: No known repair kit, only field expedient solutions.

Force Projection: This system appears to be more deployable and transportable than the system it could replace.

3.1.9 Deployable Metering and Monitoring System (DMMS)

3.1.9.1 System Description

The DMMS is a multi-component electronic system for monitoring, data acquisition, analysis, and information dissemination of base camp sustainment and logistics elements (e.g., energy, fuel, water, waste, etc.).

The three components of DMMS are:

Figure 26: DIACAP Approved Wireless Metering Solution

- DIACAP[1] Approved Wireless Metering Solution (shown in **Figure 26** interfacing with a generator set) – A suite of electrical meters and sensors to monitor base camp functional elements. The Wireless Metering Solution box:
  - Provides in-line advanced electrical meters and sensors for monitoring base camp supply and demand-side power
  - Monitors fuel status in gensets and temperature status in facilities
  - Includes meters and sensors that are enclosed in portable transit cases to facilitate rapid deployment and setup
  - Connects to open architecture dashboard

Figure 27: CB-EMS Dashboard

- Contingency Base-Energy Management System (CB-EMS) – A computerized dashboard (**Figure 27**) for data acquisition and analysis of base camps sustainment and logistics elements. The CB-EMS:
  - Provides a dashboard to facilitate informed decision making
  - Allows for control over end uses to help manage base camp energy consumption
  - Enables data analysis that provides a means for data collection and visualization
  - Provides reports for individual meters, systems, buildings, camps, or multiple camps
  - Transmits data to Operational Energy (OE) data repository

- Wide Area Visualization Environment (WAVE) – A computerized visualization tool (**Figure 28**) that:
  - Provides a cyber-secure web portal for review of base camp data at Regional, Command, and Theater levels

---

[1] DoD Information Assurance Certification and Accreditation Process (DIACAP)

- Integrates data from multiple systems for monitoring, management, and planning of operational energy use
- Displays data analytics and location information in customizable views using the toolset analytical and Geographic Information Systems capabilities
- Provides automated data transfer using standardized data formats on a secure NIPRNET (Non-Secure Internet Protocol Router NETwork) connection

Figure 28: WAVE Visualization Tool

The DMMS is currently at TRL 5+.

Technical POC: Charles T. Decker, ERDC, charles.t.decker.civ@mail.mil, 217-373-3361.

3.1.9.2 Technology Assessment

The Technology Assessment for DMMS is pending submission of attribute data from the sponsoring agency.

3.1.10 Structural Insulated Panel Hut (SIP-Hut)

3.1.10.1 System Description

The SIP-Hut (**Figure 29**) is an alternative to semi-permanent barracks (commonly known as barracks huts or B-Huts). The SIP-Huts are constructed of pre-manufactured structural insulated panels that have a high insulating value (both thermal and acoustic), and provide for quick assembly and disassembly. The SIP-Hut takes one-third the time to construct and is twice as energy efficient as the current B-Huts.

Figure 29: SIP-Hut [left] and B-Hut [right]

Important features of the SIP-Hut are:

- Reduction in energy consumption compared to non-insulated B-Hut
- 50-60% reduction in squad-hours construction time compared to B-Hut (not including roof) with non-skilled labor

The SIP-Hut is currently at TRL 6.

Technical POC: Melvin Jee, NSRDEC, melvin.w.jee.civ@mail.mil, 508-233-5245.

3.1.10.2 Technology Assessment

Attributes for the SIP-Hut were not scored before the DAG. See attribute data in Annex B.10.

3.2 Fuel Reduction – Supply Side

Table 10 contains a list of the technologies examined for potential fuel reduction on the supply side.

Table 10: Fuel Reduction-Supply Side - Technologies

ID	Technology/Component	Lab/ RDEC
EE-0030	HMMWV-Towable, Load-Following 100 kW Power Unit (T100)	CERDEC
EE-0060	Single Common Powertrain Lubrication (SCPL)	TARDEC
EE-0360	Energy Informed Operations – Central (EIO-C)	CERDEC
EE-1070	Man-Portable Genset for Power Generation for Expeditionary Small Unit Operations (MANGEN)	CERDEC
EE-1210	Hybrid Power Trailer (HPT)	ERDC

3.2.1 HMMWV-Towable, Load-Following 100 kW Power Unit (T100)

3.2.1.1 System Description

Figure 30: T100 Genset on Trailer

Power and energy requirements in a rapidly modernized, modular, highly digital and network-centric Army are growing exponentially. This growth imposes a significant logistics burden on fuel consumption, power density, reliability, and environmental issues. Transportation of generator sets to the battlefield is a logistical burden due to the weight of the large generator sets of 30kW and up. CERDEC's Command, Power, & Integration Directorate is working in conjunction with PM E2S2 to leverage a previous science and technology investment and further mature the T100 (**Figure 30**). Investments supported development of critical enablers such as innovative combustion enhancements, JP-8 fuel conditioners, advanced power electronic controls, and thermal management solutions. The T100 integrates a commercial off-the-shelf (COTS) engine and energy storage technology, resulting in a highly power dense, fuel efficient 100 kW system that reduces the logistics and transportation burdens of the battlefield. The T100 reduces the weight of the skid-mounted 100 kW Tactical Quiet Generator (TQG) from 5880 lb to

2500 lb, enabling it to be trailer-mounted (4000 lb with trailer) and towed behind a High Mobility, Multi-purpose Wheeled Vehicle (HMMWV) or Joint Light Tactical Vehicle.

The T100 demonstrated the following capabilities and products:

- Improved fuel efficiency which reduces operations and support costs and logistics burden of fuel resupply (less fuel than current 100 kW TQG)
- Continuous power output of 80 kW (0.8 power factor (PF)) [NOTE: The objective is 100 kW of continuous power output, hence the name T100.]
- 120/208 volts alternating current (four wire), three-phase, 60 hertz (Hz)
- Use of an integrated fuel tank sized to allow 8 h of operation at 100% load
- Use of load-following system to reduce fuel consumption at low loads, reduce component wear, and reduce noise signature
- Reduced noise signature to enhance Soldier survivability and reduce Soldier fatigue
- Enhanced reliability by 15%

The T100 is currently at TRL 6 and pending transition to PM E2S2 at TRL 7 and to PdM-FSS in support of the power requirements for Force Provider.

Technical POC: US Army CERDEC, usarmy.apg.cerdec.mail.cerdec@mail.mil.

3.2.1.2 Technology Assessment

Figure 31 contains the Technology Assessment scoring information for the T100.

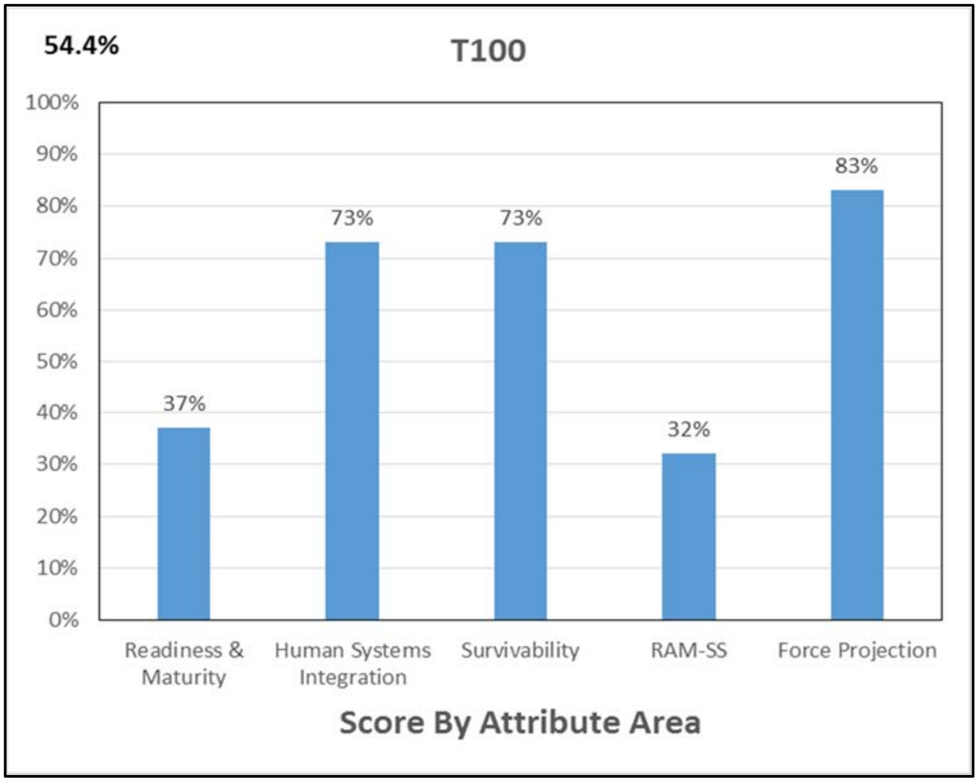

Figure 31: Technology Assessment Graph for the T100

Readiness and Maturity: While the T100 shows great promise, the current information is based on a single prototype. More evaluation is recommended as this system continues to mature.

Human Systems Integration: A redesign has been recommended to make the system easier to repair in the field.
Survivability: The system currently has no protection from high-altitude electromagnetic pulse (HEMP) or CBRN contaminants.

RAM-SS: The system experienced a catastrophic failure during demonstration. The system was expeditiously repaired and put back into service. There were design recommendations made to prevent such failures in the future.

Force Projection: This system is easily maneuverable with a prime mover.

3.2.2 Single Common Powertrain Lubrication (SCPL)

3.2.2.1 System Description

The SCPL (**Figure 32**) will provide a superior powertrain lubricant that will reduce fuel consumption, logistics burden, and maintenance requirements.

The SCPL will demonstrate the following capabilities and products:

- At least two qualified products meeting the requirements of SCPL (i.e., full synthetic, all temperature, combined engine and transmission lubricant, with extended oil change interval, superior high temperature stability, and improved fuel economy)
- New performance-based specification (Open Standards for Centrally Controlled Intelligent Power System Interfaces) allowing the competitive procurement of SCPL

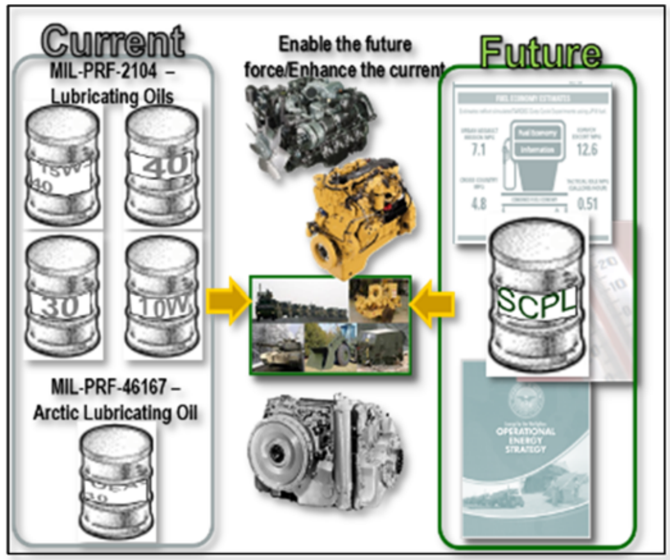

Figure 32: Single Common Powertrain Lubrication

Demonstration of the above capabilities and products will provide:

- Reduced risk, save Soldiers' lives and lower costs by reducing fuel logistics burden (i.e., reduced number of fuel convoys) with more fuel-efficient lubricant
    - $6.5M annually in fuel savings based on $5.85/gal fuel cost (2006 dollars)
    - 15,000 fewer trips to transport fuel from a 1% reduction in fuel demand
- Reduced lubricant resupply and waste disposal by increasing oil life by ≥ 2 times
- Reduced misapplications and equipment downtime (i.e., multifunctional usage)
- Enhanced lubricant capabilities improve vehicle performance for more power and torque
- Increased equipment readiness by increasing reliability and durability

The SCPL is currently at TRL 7 and transition to a Program of Record (POR) is pending. ***Technical POC***: Allen Comfort, TARDEC, allen.s.comfort.civ@mail.mil, 586-282-4225.

3.2.2.2 Technology Assessment

Figure 33 contains the Technology Assessment scoring information for the SCPL.

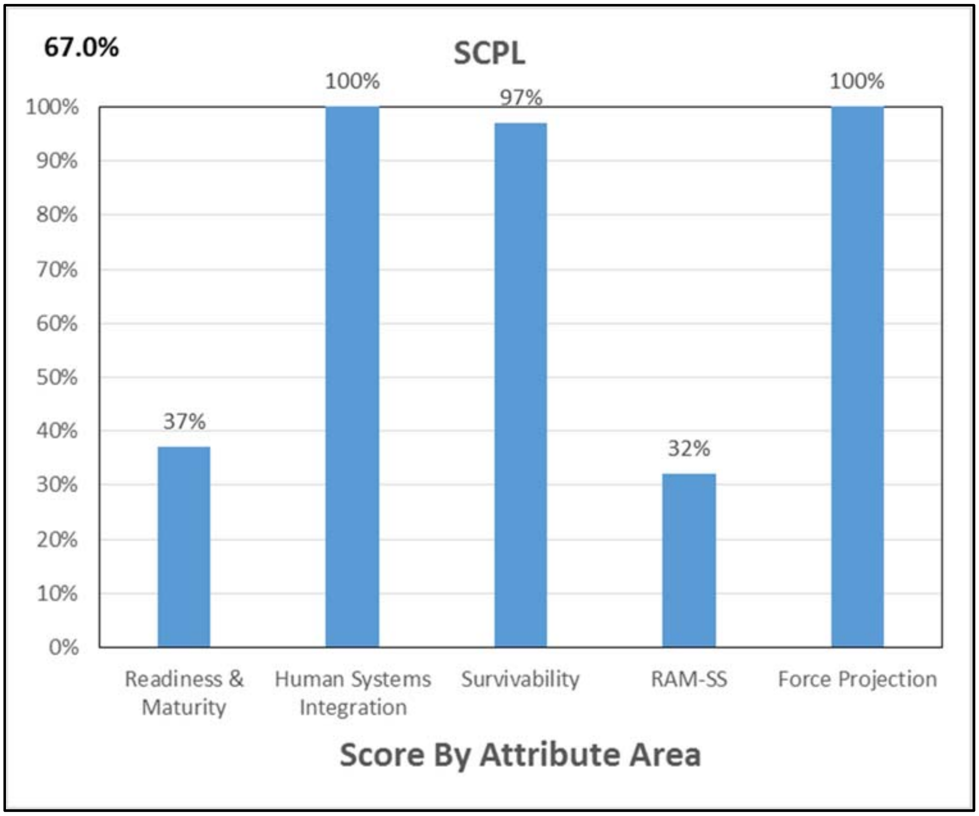

Figure 33: Technology Assessment Graph for the SCPL

Readiness and Maturity: This product requires more evaluation in gensets to determine if it meets the same high performance as demonstrated in vehicles.

Human Systems Integration: HSI attributes for this product are the same as for current POL.

Survivability: Like all POL products, this product will breakdown eventually. However, it may last longer than most and offers a distinct advantage.

RAM-SS: More evaluation is required in gensets to determine RAM characteristics.

Force Projection: This product is transported the same as current POL products. Footprint could be improved since less product is needed due to less frequent oil changes.

3.2.3 Energy Informed Operations – Central (EIO-C)

3.2.3.1 System Description

The EIO-C (**Figure 34**) will develop, implement, and support an intelligent power system interface standard and associated applications which allow optimization of power and energy resources based on mission objectives. The EIO-C is composed of the following components, equipment, and systems:

- Laptop to monitor power and status of the grid (lower left **Figure 34**)
- Two 60 kW and two 30 kW TQGs (**Figure 35**)
- One 60 kW/106 kilowatt-hour (kWh) Inverter/Battery system (**Figure 36**)
- Four Intelligent Power Distribution–200 (IPD200) boxes (**Figure 37**)

Figure 34: Energy Informed Operations-Central

Figure 35: TQGs

Figure 36: Inverter/Battery System

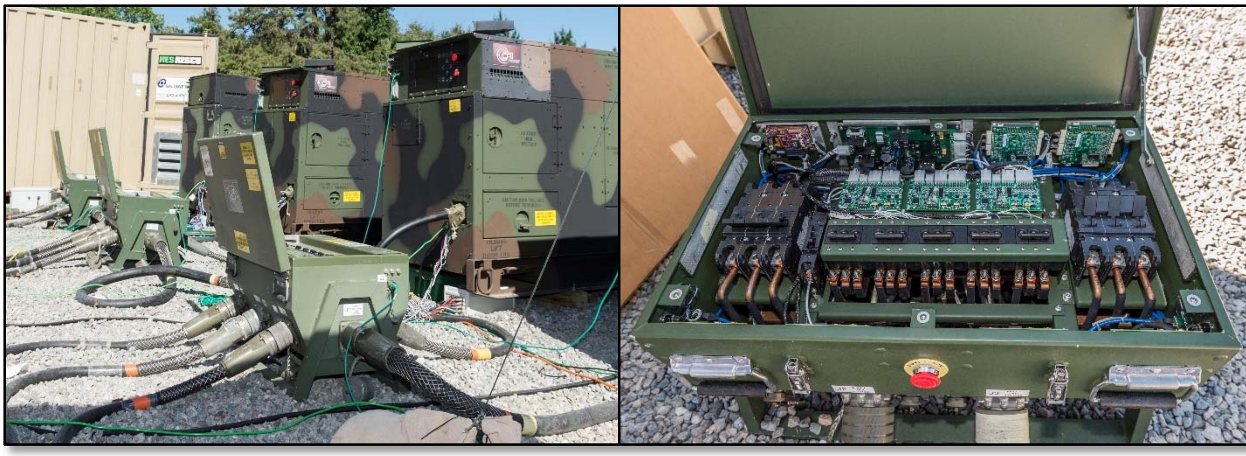

Figure 37: IPD200

The EIO-C delivers the following capabilities and products:

- Open standards for centrally controlled intelligent power system interfaces
- Applications for awareness and control of power resources

The above capabilities and products will provide:

- Improved efficiency in operational energy to reduce costs and logistics burden of fuel resupply
- Ability to prioritize and utilize power resources according to mission needs, thus enabling commanders with information and flexibility to complete the mission in a resource-constrained environment
- More reliable and resilient energy network to ensure the availability of power across the battlespace

The EIO-C is currently at TRL 5 and scheduled to transition at TRL 6 to support the PM E2S2's Management and Distribution Control program in FY18/19.

Technical POC: Michael Gonzalez, CERDEC, michael.l.gonzalez.civ@mail.mil, 443-395-4381.

3.2.3.2 Technology Assessment

Figure 38 contains the Technology Assessment scoring information for the EIO-C.

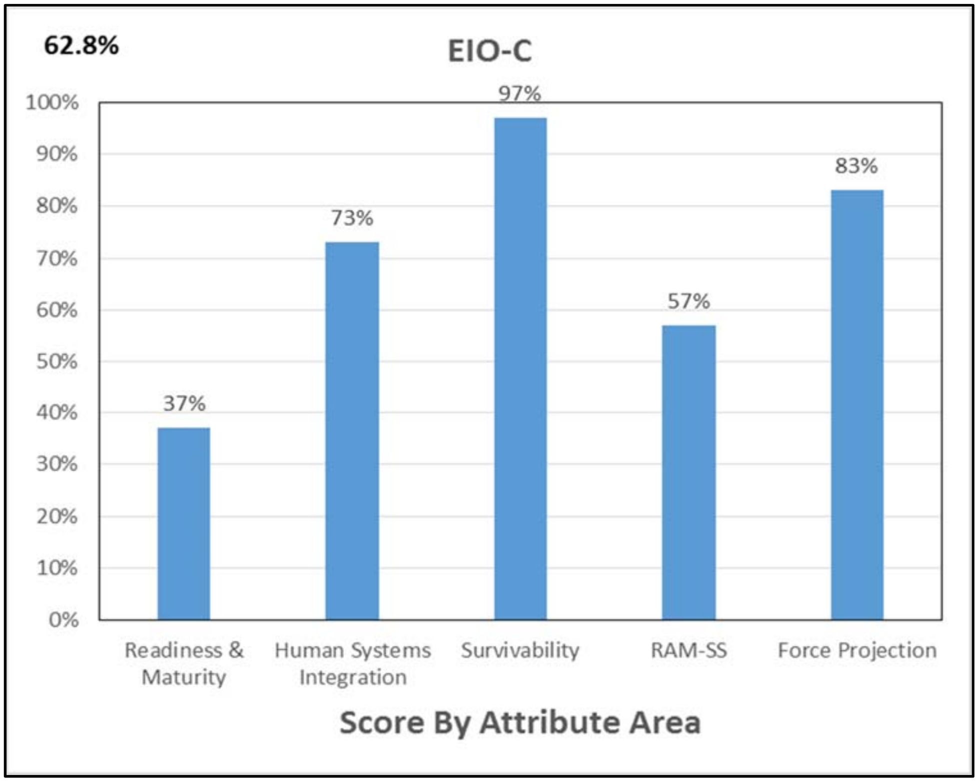

Figure 38: Technology Assessment Graph for the EIO-C

Readiness and Maturity: This system requires more evaluation with various mix of loads, generators, and alternate power sources and power storage solutions to continue software development.

Human Systems Integration: The EIO adds another level of human systems integration to make a smart microgrid from a "dumb" grid. While the fuel savings will pay off, the cost is additional boxes, cables, connections, computers, and software that will require training and oversight.

Survivability: The inherent feature of the microgrid is that there is excess capability and it is expected that the system could continue to provide essential power through certain adverse events.

RAM-SS: This system should inherently increase the RAM of generators by not running them as often and reducing wet-stacking.

Force Projection: If the IPDs of the microgrid replace, but don't add to, the number of required distribution boxes, then Force Projection of this system is comparable to the baseline.

3.2.4 Man-Portable Genset for Power Generation for Expeditionary Small Unit Operations (MANGEN)

3.2.4.1 System Description

The MANGEN (**Figure 39**) is a man-portable generator set capable of delivering up to 1 kWe (kilowatt-electric). It utilizes COTS spark ignition engines modified with a catalyst-based conversion kit to burn JP-8 instead of exclusively gasoline. The MANGEN provides enhanced mission capabilities for expeditionary small unit operations by providing electrical power in a compact, lightweight unit that reduces fuel and maintenance costs, while reducing procurement costs.

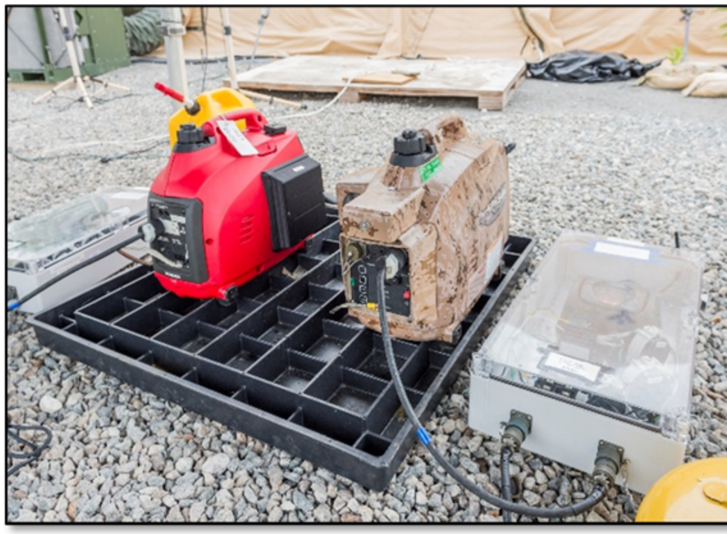

Figure 39: Man-Portable Genset for Power Generation

Other MANGEN characteristics are:

- High power density (< 34 lb for 750 W)
- Multi-fuel
- Efficient across load profile
- Rapid start-up in cold conditions
- Load following, i.e., no wet stacking
- Spinoffs:
    - 2 kW multi-fuel generator < 50 lb
    - 3 kW multi-fuel electric start generator < 200 lb
    - Applications for heavy fuel burners and for catalytic beds (fuel cells, fuel processors)

The MANGEN is currently at TRL 7 and scheduled to transition to PM E2S2 at TRL 8. The transition timeline is pending.

Technical POC: Ed Nawrocki, CERDEC, edmund.a.nawrocki2.civ@mail.civ, 443-395-4799.

3.2.4.2 Technology Assessment

Figure 40 contains the Technology Assessment scoring information for the MANGEN.

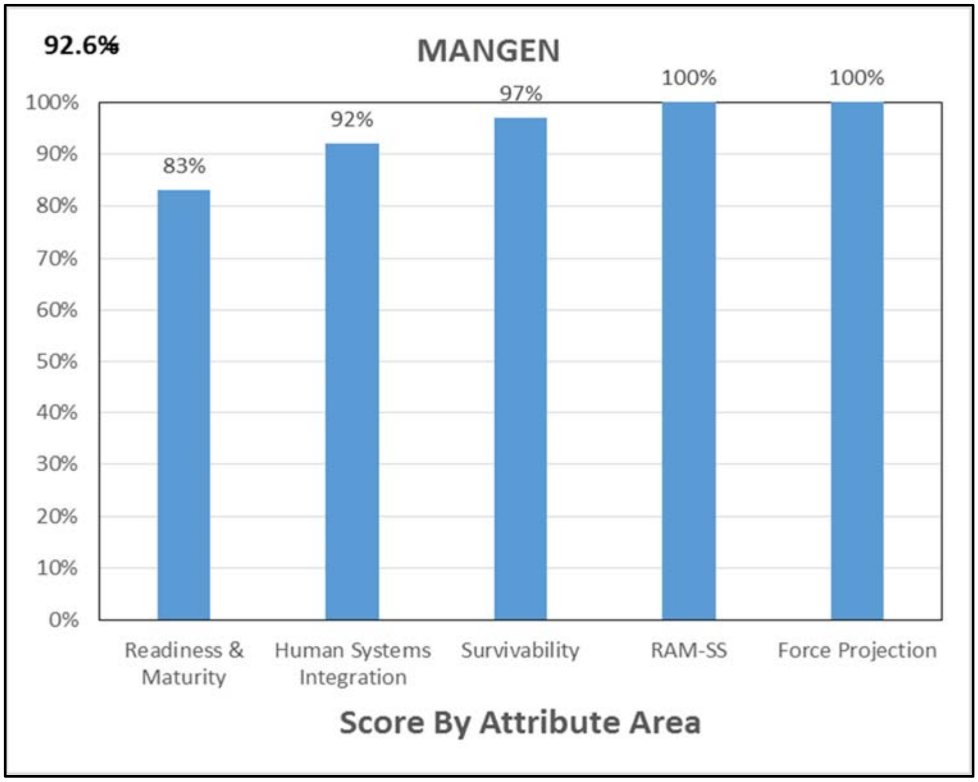

Figure 40: Technology Assessment Graph for the MANGEN

Readiness and Maturity: Indications are this system is fairly mature at this point. Some vendor units performed better than others at demo, and some issues were identified with certain models. Vendors are aware of corrections to be made.

Human Systems Integration: This system is based on a widely acceptable COTS product. Users must treat the system with respect to the possibility of electrical shock and understand the fuel-handling hazards.

Survivability: The system is based on a COTS product and has the associated vulnerabilities to an operational environment, i.e., HEMP and CBRN.

RAM-SS: This system is expected to be highly reliable and easily supportable. This is a positive feature of the COTS platform.

Force Projection: This system meets the Army's need for a small, portable genset. It is easily deployable and transportable.

3.2.5 Hybrid Power Trailer (HPT)

3.2.5.1 System Description

The HPT (**Figure 41**) is an electrical power generation system that coupled a standard Army 15 kW TQG with an 80 kWh lithium ion battery mounted on a trailer. The system was designed to

decrease generator run time, reduce fuel consumption, enable silent operation, and provide power redundancy for military applications.

Important characteristics of the HPT are:

- Reduces fuel consumption by 80% (54 gallons/day (gpd) down to 11 gpd) during spring and summer testing at the ERDC Construction Engineering and Research Laboratory in Champaign, IL
- Provides 28 h of silent operation at low loads (< 2 kW)

Figure 41: Hybrid Power Trailer

The HPT is currently at TRL 6, and transition to a POR is pending.

Technical POC: Charles T. Decker, ERDC, charles.t.decker.civ@mail.mil, 217-373-3361.

3.2.5.2 Technology Assessment

The Technology Assessment for the HPT is pending submission of attribute data from the sponsoring agency.

3.3 Water Reduction

Table 11 contains a list of the technologies examined for potential water reduction.

Table 11: Water Reduction - Technologies

ID	Technology/Component	Lab/ RDEC
EE-0790	Modular Force Water Generation Storage & Analysis (WFA)	TARDEC
EE-0820	Real Time Inline Diagnostic Technology (WATERMON)	TARDEC
EE-0830	Rapid Identification and Quantification in Water – Pathogen Monitor (PM)	TARDEC
EE-0850	Water Conservation Technology (WCT) for Mobile Kitchens & Sanitation Centers	NSRDEC
EE-0862	Graywater Reuse System – Forward Osmosis/Reverse Osmosis (FORO)	TARDEC
EE-1090	Efficient Water Reuse Technologies for COBs (G-WTRS)	ERDC
EE-1160	Water Demand Reduction Technologies - Shower Heads (WDR-S)	NSRDEC

3.3.1 Modular Force Water Generation Storage & Analysis (Water From Air - WFA)

3.3.1.1 System Description

The WFA system (**Figure 42**) generates water from atmospheric humidity using absorption/desorption desiccant technology, energy recovery, and condensation. The system provides next generation water production and distribution capabilities through mobile water-from-air generation and storage. The system is mounted on a 7.5-ton trailer and produces up to 500 gpd.

Figure 42: Water From Air

The WFA provides the following benefits:

- Fills WFA capability gap identified in Petroleum & Water Functional Solutions Analysis
- Reduces the logistical footprint associated with bulk liquid storage and distribution by 50 to 75%
- Economic analysis using the Sustain the Mission Project methodology demonstrates payback in less than 1 year
- Reduces or eliminates base camp water resupply

The WFA is currently at TRL 6 and transition to Product Manager – Petroleum & Water Systems (PdM-PAWS) is pending.

Technical POC: Lateefah C. Brooks, TARDEC, lateefah.c.brooks.civ@mail.mil, 586-282-6587.

3.3.1.2 Technology Assessment

Figure 43 contains the Technology Assessment scoring information for the WFA.

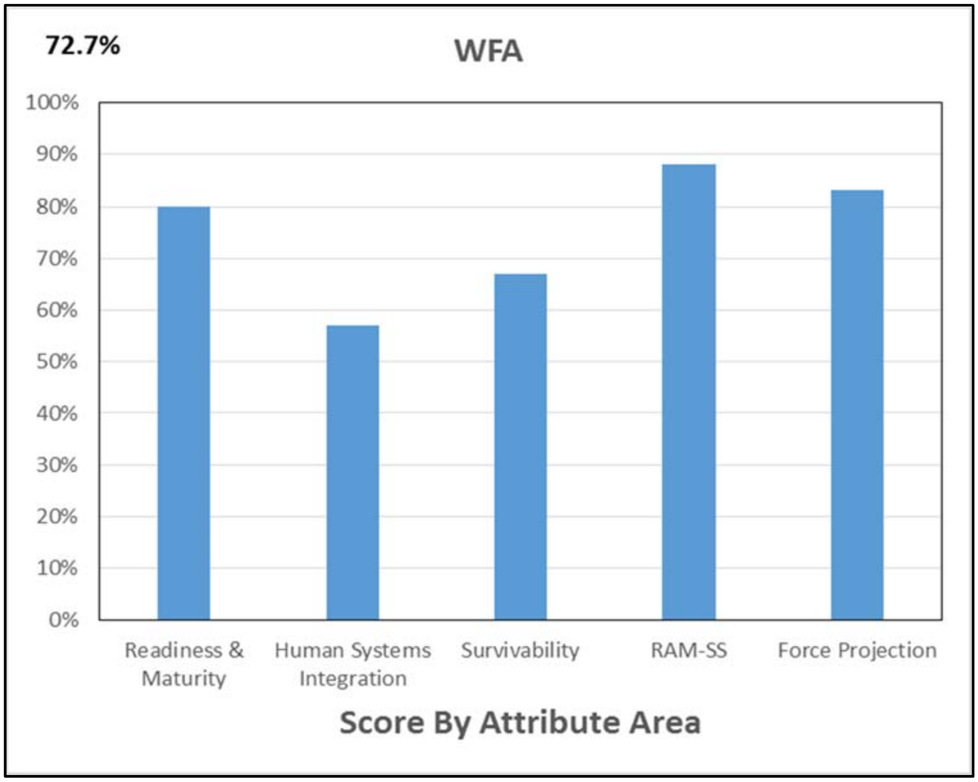

Figure 43: Technology Assessment Graph for the WFA

Readiness and Maturity: This is a novel and promising technology.

Human Systems Integration: It is noted that some maintenance tasks will be difficult. Some effort could be put into redesign to improve the HFE for maintenance and for operation and viewing of the screen.

Survivability: This system has no known degraded modes.

RAM-SS: While the true RAM parameters are unknown at this time, this system should be logistically supportable.

Force Projection: This system, in the quantities suggested by the ISS, will require additional transport. This may be offset some by other water transport or storage assets that perhaps may not deploy as a result of significant water generation.

3.3.2 Real Time Inline Diagnostic Technology (WATERMON)

3.3.2.1 System Description

The WATERMON (informally, "water monitor") (**Figure 44**) system consists of a suite of sensors for inline water monitoring applications. The system is a water demand reduction technology capable of providing quality assurance information for >30 days use of field water produced using new processing techniques. The system is also capable of enabling the

performance optimization of water treatment equipment.

Other important characteristics of the system are:

- Autonomous, battery powered
- Wireless and network-capable sensors compatible with most computing devices, smart phones, and media players
- Interoperable with most water treatment and handling systems using supplied connections
- Testing raw and product water with <5% inaccuracy for each water quality parameter and <5 min total analysis time
- Non-specific MOS operator can be trained within 2 h

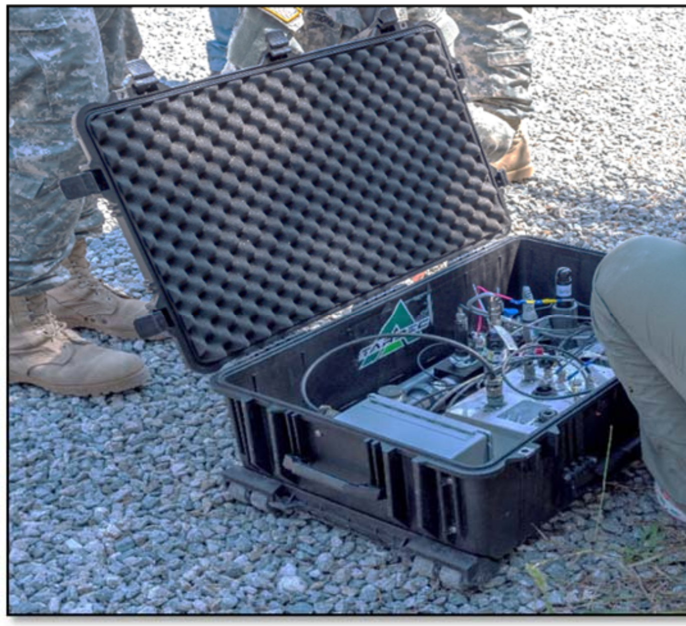

Figure 44: Water Monitor

The WATERMON is currently at TRL 5 and will be transitioned to PdM-PAWS at TRL 6+ at a time to be determined.

Technical POC: Lisa Neuendorff, TARDEC, Lisa.Neuendorff@us.army.mil, 586-282-4161.

3.3.2.2 Technology Assessment

Figure 45 contains the Technology Assessment scoring information for the WATERMON.

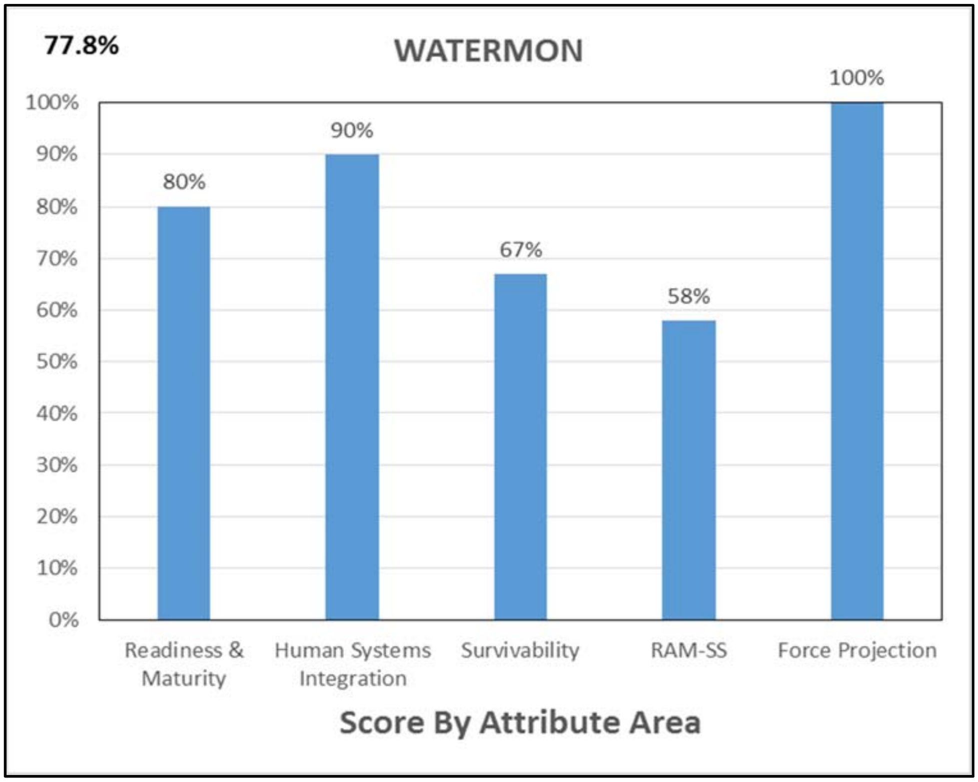

Figure 45: Technology Assessment Graph for the WATERMON

Readiness and Maturity: The system is on a good developmental path.

Human Systems Integration: There are no serious HSI issues.

Survivability: The fragility of probes and electrodes will make this system susceptible.

RAM-SS: Replacement probes will need to be available to replace as they break.

Force Projection: This is a very small system and there are no force projection issues.

3.3.3 Rapid Identification and Quantification in Water – Pathogen Monitor (PM)

3.3.3.1 System Description

The PM (**Figure 46**) system consists of a smart cell phone-based pathogen detection kit to solve challenges to contaminant detection and process verification for mobile water treatment and supply systems. Important benefits of the system are:

- Reduces Army convoys by solving capability gap for long-term tactical water purification – skilled manpower for equipment complexity – and improving efficiency of water treatment and production
- Protects Soldier health through improved process monitoring

The PM is currently at TRL 6 and will be transitioned to PdM-PAWS at TRL 6+ at a time to be determined.

Technical POC: Lisa Neuendorff, TARDEC, Lisa.Neuendorff@us.army.mil, 586-282-4161.

3.3.3.2 Technology Assessment

Figure 47 contains the Technology Assessment scoring information for the PM.

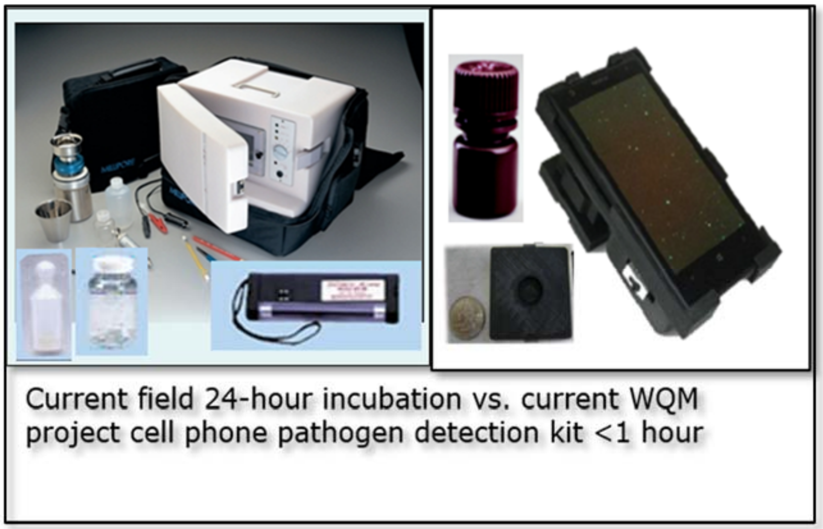

Figure 46: Pathogen Monitor

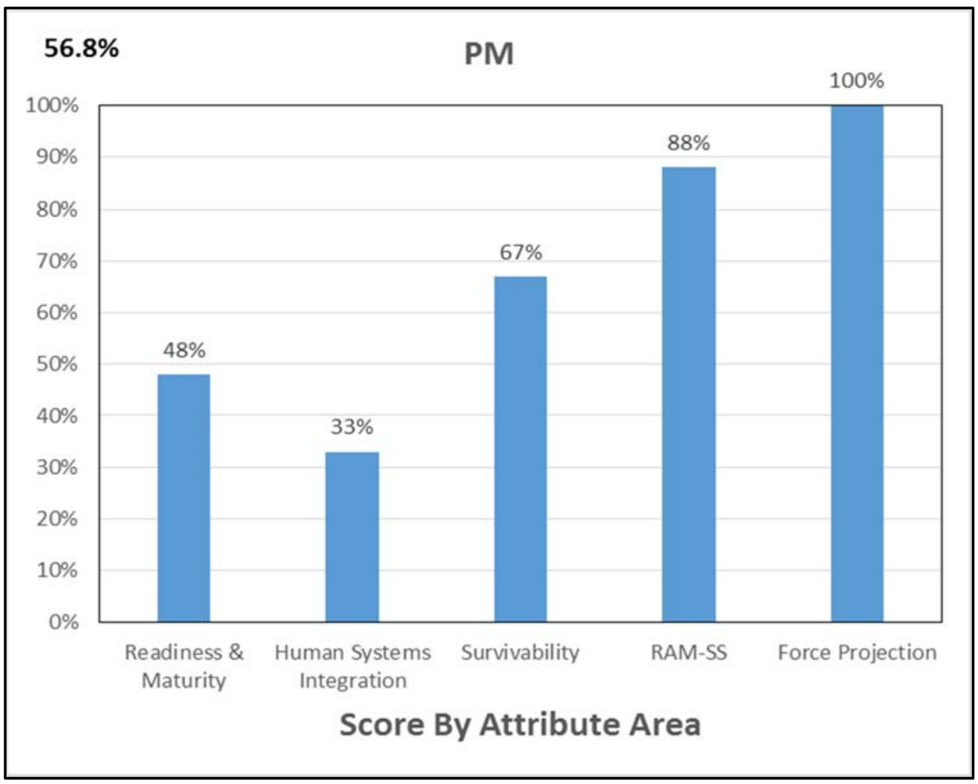

Figure 47: Technology Assessment Graph for the PM

Readiness and Maturity: Some design changes are required to make this system more user friendly.

Human Systems Integration: This system is difficult to use. Requires more research and development.

Survivability: The system is as survivable as the host cell phone.

RAM-SS: The system is easily supportable and expected to be durable with little to no maintenance requirements.

Force Projection: There are no force projection issues associated with this system.

3.3.4 Water Conservation Technology (WCT) for Mobile Kitchens & Sanitation Centers

3.3.4.1 System Description

The WCT (**Figure 48**) is a system that reduces water and fuel required for maintaining field foodservice sanitation. The modular system is comprised of low-powered, portable, water recycling, and additional kitchenware washer/booster heater components.

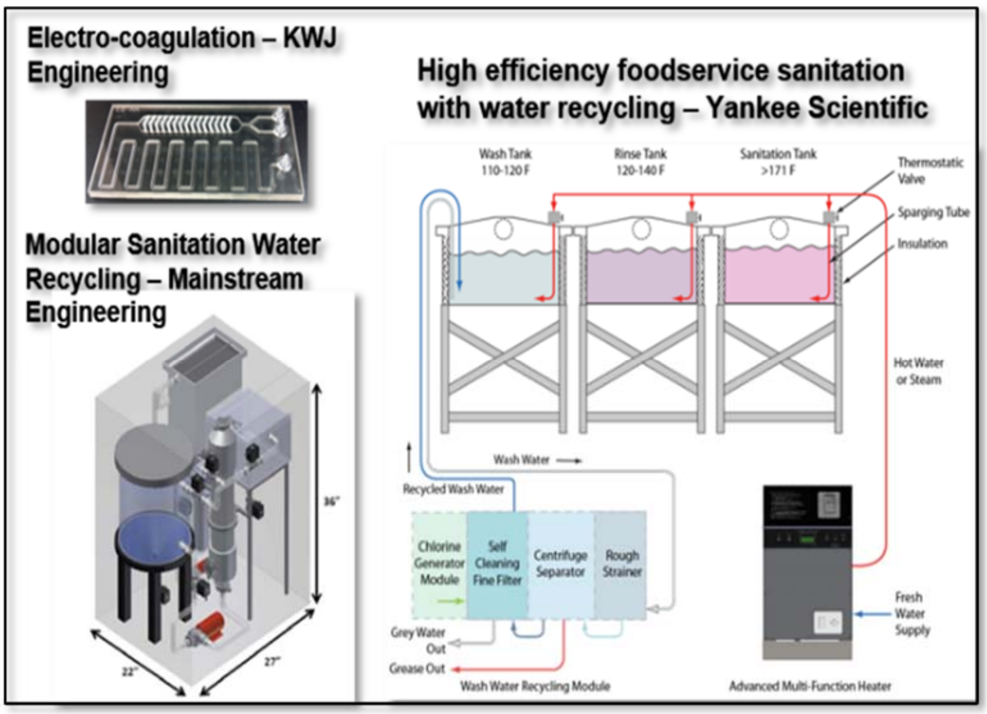

Figure 48: Water Conservation Technology

Significant attributes of the WCT are:

- Modular, man-portable components (147 lb target)
- Maintains a reliable, safe, efficient, field foodservice sanitation capability that significantly reduces water and fuel requirements
- Supports a full range of military field kitchens (e.g., Assault Kitchen, Assault Kitchen – Enhanced, Mobile Kitchen Trailer – Enhanced, Modernized Basic Expeditionary Airfield Resources 550 Kitchen, Electric Single Pallet Expeditionary Kitchen, Expeditionary Field Kitchen, Force Provider Kitchen, as well as future field kitchen platforms)

The benefits and payoffs of the WCT are:

- Clarifies and recirculates sanitation water to significantly reduce water requirement. The addition of the automatic kitchenware washer contributes to the SLB-STO-D's objective to reduce water consumption by 75%
- Reduces water demand for Force Provider Kitchen
- Development continues under an Army SBIR Phase II Enhancement through 2018

The WCT is at TRL 5 and transition to PdM-FSS is pending.

Technical POC: Peter Lavigne, NSRDEC, peter.g.lavigne.civ@mail.mil, 508-233-4939.

3.3.4.2 Technology Assessment

Figure 49 contains the Technology Assessment scoring information for the WCT.

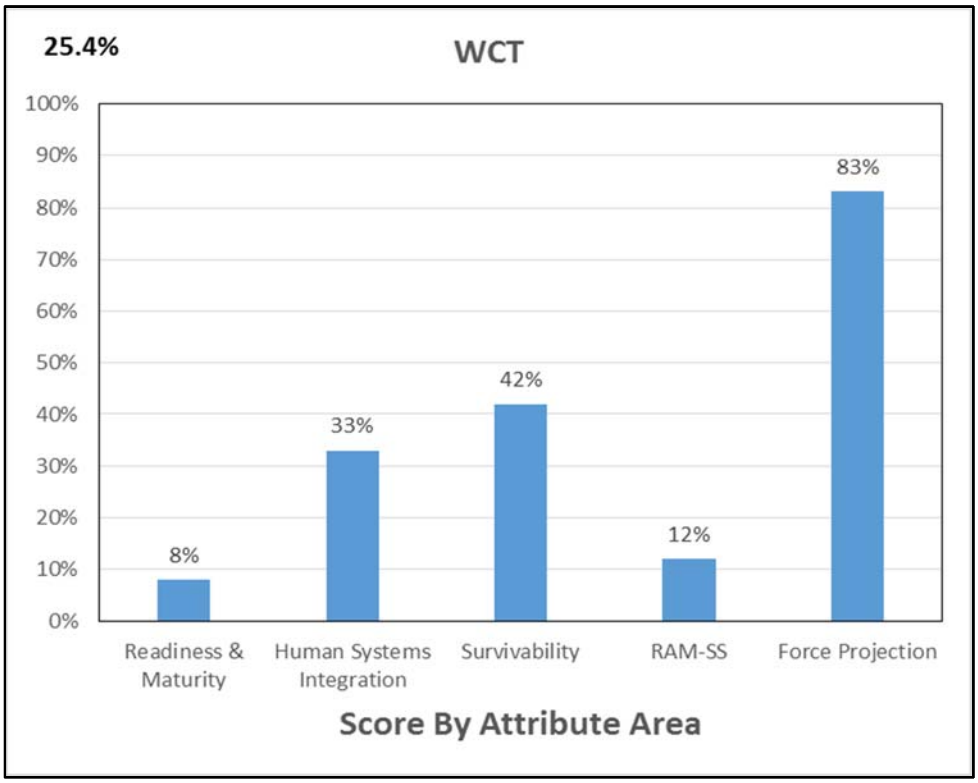

Figure 49: Technology Assessment Graph for the WCT

Readiness and Maturity: This system is still early in its development cycle.

Human Systems Integration: This system is still early in its development cycle and the HSI characteristics are not well known.

Survivability: This system is a single prototype and not yet optimized for military use.

RAM-SS: RAM is still to be evaluated.

Force Projection: Although the system is immature, there is no reason to believe the form factor will not be easily transportable.

3.3.5 Graywater Reuse System – Forward Osmosis/Reverse Osmosis (FORO)

3.3.5.1 System Description

The FORO **(Figure 50)** technology project provides graywater recycle/reuse at contingency bases to reduce non-potable water resupply needs. It also provides an improved capability that can adapt to widely varying load conditions to treat more influent streams with less fouling and increased recovery of treated water.

Figure 50: Graywater Reuse System – Forward Osmosis/Reverse Osmosis

The FORO entailed the following components:

- TRICON containing FORO system (**Figure 51**).
- Graywater blivet (3000 gal) to store graywater output of laundry, showers, and sinks **(Figure 35**).
- Wastewater onion tank (3000 gal) to store wastewater processed by the FORO (**Figure 53**).

Figure 51: FORO within a TRICON

Figure 52: 3000-gal Graywater Tank

The FORO technology project demonstrated the following capabilities and products:

Figure 53: 3000-gal Non-potable Water Tank

- A graywater reuse technology that can be integrated into current support equipment to include:
  - Water purification systems
  - Shower and laundry systems
  - Field feeding and medical systems
- Characteristics:
  - Weight: ≤7,110 lb
  - Size: pack out volume of ≤ 416 ft^3
  - Cost target: <$250K per unit for production >100
  - Manpower: minimal, with automatic control and operation

Demonstration of the above capabilities and products will provide:

- Reduction in transportation assets required to haul wastewater and provide potable water currently used for non-potable uses
- Expected reduction in the water logistical footprint of 75%
- Improved safety and force protection at base camps
- Reduction in water, fuel, and waste
- Reduction in health risks from wastewater-associated vectors

The FORO technology project is currently at TRL 5 and scheduled to transition to PdM-PAWS at TRL 6 in FY 18.

Technical POC: Lateefah Brooks, TARDEC, lateefah.c.brooks.civ@mail.mil, 586-282-6587.

3.3.5.2 Technology Assessment

Figure 54 contains the Technology Assessment scoring information for the FORO.

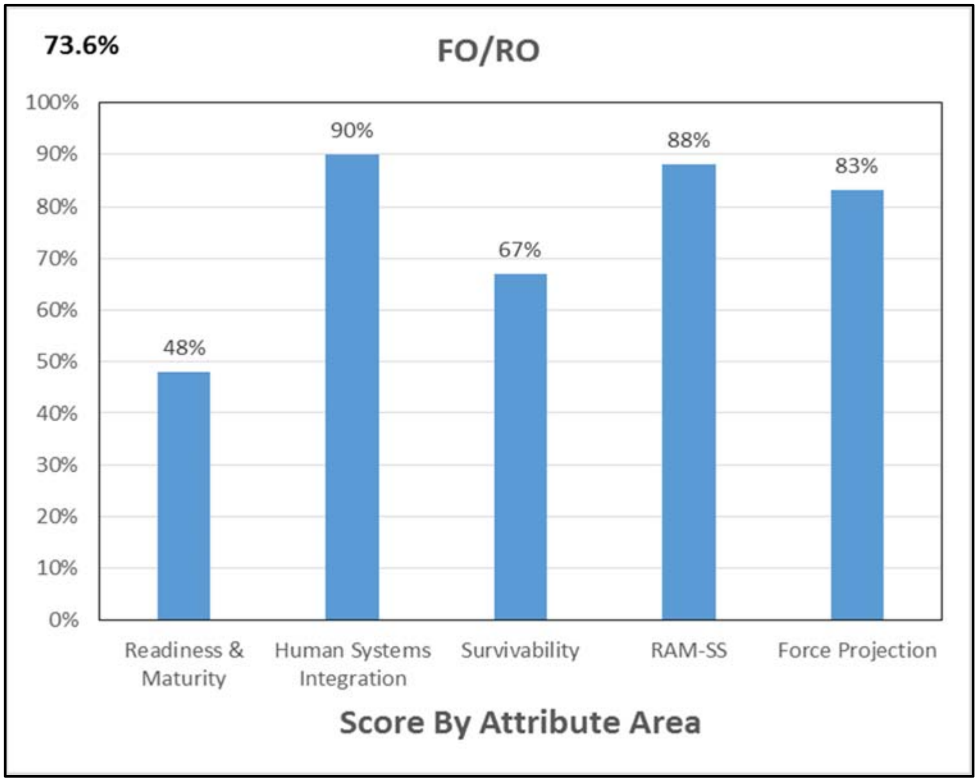

Figure 54: Technology Assessment Graph for the FORO

Readiness and Maturity: Some design changes have been recommended by the Technology Provider to make the system scalable.

Human Systems Integration: The system is not overly complex. The Technology Provider has recommended some design changes to make certain components more accessible.

Survivability: While the container is military hardened, the working components are not.

RAM-SS: Pumps, etc., are well known and basically reliable. The forward osmosis stack, including membrane maintenance, is less well understood than standard membranes.

Force Projection: This system will not present an unusual challenge for transportation or space for setup.

3.3.6 Efficient Water Reuse Technologies for COBs (G-WTRS)

3.3.6.1 System Description

G-WTRS (informally, Graywater Treatment and Reuse System) (**Figure 55**) is a program to design, assemble, and evaluate a robust, operationally-efficient water reuse system that can reduce water demand at Contingency Operating Bases (COBs).

Important accomplishments of the program are:

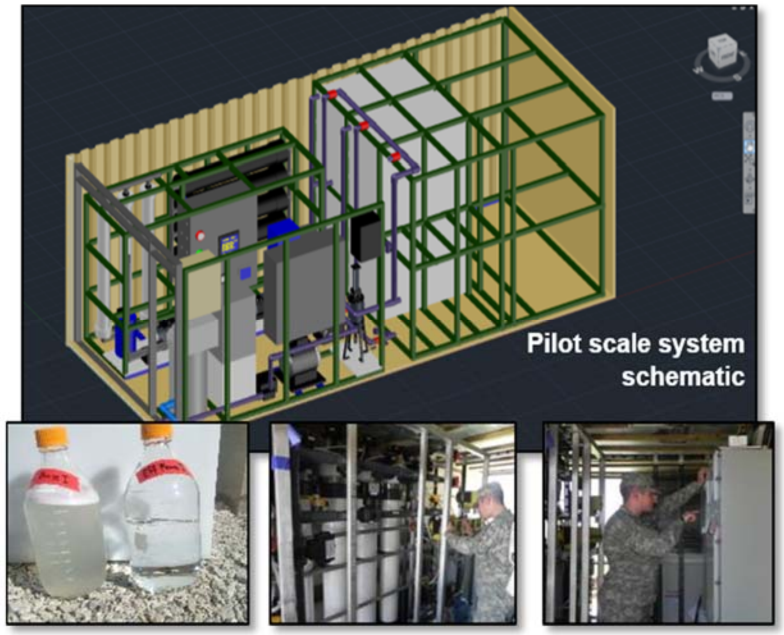

Figure 55: Efficient Water Reuse Technologies for COBs

- Robust biofiltration pre-treatment systems that can tolerate intermittent flows and produce water for low-tier reuse applications (e.g., toilet flushing, equipment washing) or further treatment for high-tier reuse (e.g., showering, laundry)
- Scalable, high-flux reverse-osmosis membrane systems that operate at low pressure to efficiently purify graywater for high-tier reuse applications
- An integrated, robust, and operationally-efficient graywater reuse system for 600-1000 personnel camps, which can be easily extended to other Army water treatment applications
- Detection and quantification of Pb (lead) and ClO_4 (perchlorate)

The G-WTRS is currently at TRL 6 and transition to a POR is pending.

Technical POC: ERDC, erdcpublicaffairs@usace.army.mil, 601-634-2502.

3.3.6.2 Technology Assessment

Figure 56 contains the Technology Assessment scoring information for the G-WTRS.

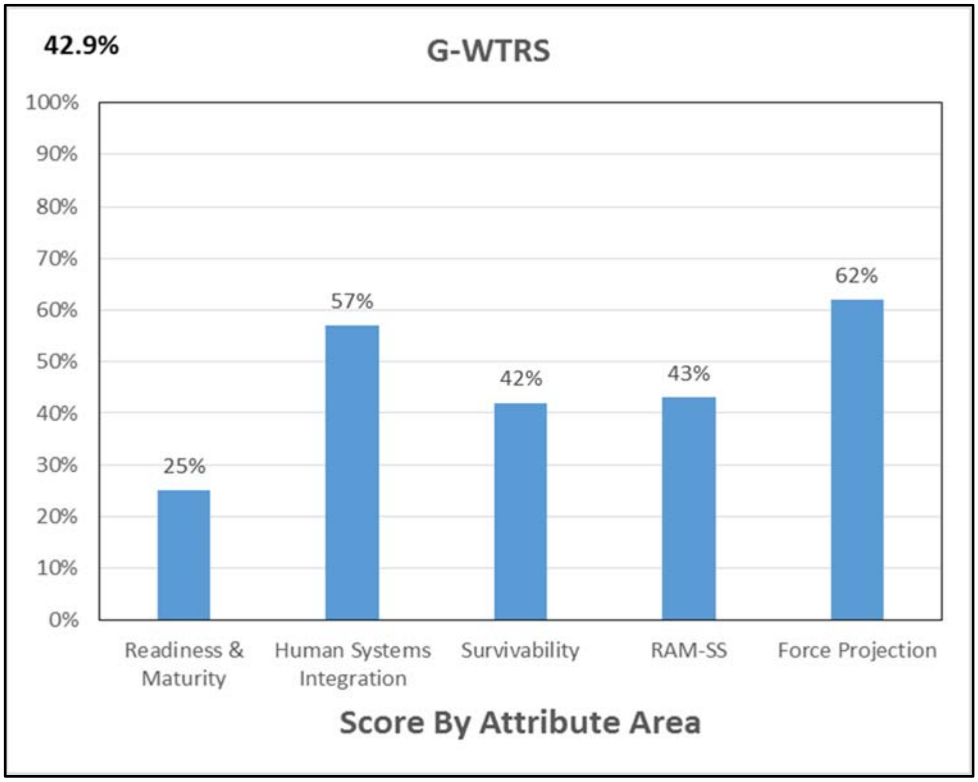

Figure 56: Technology Assessment Graph for the G-WTRS

Readiness and Maturity: This system shows great promise, but is still very immature. The current system is an R&D demonstrator and not yet at the prototype stage.

Human Systems Integration: The R&D demonstrator version of this capability scores well for HSI. Improvements can be made when this technology moves to the next level of maturity.

Survivability: This system is not yet fully ruggedized for deployment and field operations.

RAM-SS: This system is still too immature to fully assess the RAM attributes. However, it is expected to be fully sustainable and supportable.

Force Projection: This system could replace other graywater treatment systems, and therefore replaces, not adds to, load space requirements. It will be heavy and will require lift assets.

3.3.7 Exploration of Water Demand Reduction Technologies - Shower Heads (WDR-S)

3.3.7.1 System Description

The WDR **(Figure 57**) technology project investigated technologies capable of reducing or eliminating the use of water within base camp organizational equipment, such as laundries, showers, and latrines. During this technology exploration, the definition of water demand reduction requirements and program metrics will be completed. The highest payoff and manageable risk technologies will be down-selected and prototyped for demonstration.

The WDR technology project will demonstrate the following capabilities and/or products:

- Formalized water demand reduction requirements and program metrics
- Test data and validation of water demand reduction technology through small-scale laboratory experimentation
- Insertion of technology metrics into SLB-STO-D modeling and simulation environment to determine net impact to base camp water consumption
- Potential solutions include the Xeros laundry unit, a low flow showerhead, and the RTI International™ liquid disinfection system (or complete latrine system)

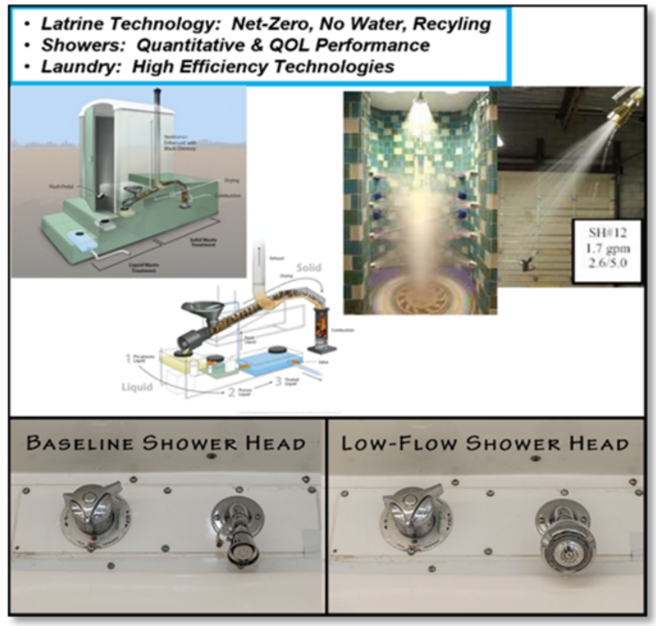

Figure 57: Water Demand Reduction Concept

The WDR-S is a sub-set of the WDR project and is limited to the low-flow showerhead seen in the bottom right of **Figure 57**.

Demonstration of these capabilities and products will provide:

- Overall reduction in base camp water demand
- Significant reduction in the cost and logistical burden associated with base camp resupply
- Fewer personnel and vehicles required to perform hazardous resupply of base camps

The WDR-S is a commercially available product and can be implemented by PdM-FSS at any time.

Technical POC: Chris Aall, NSRDEC, christian.d.aall.civ@mail.mil, 508-233-5188.

3.3.7.2 Technology Assessment

Figure 58 contains the Technology Assessment scoring information for the WDR-S.

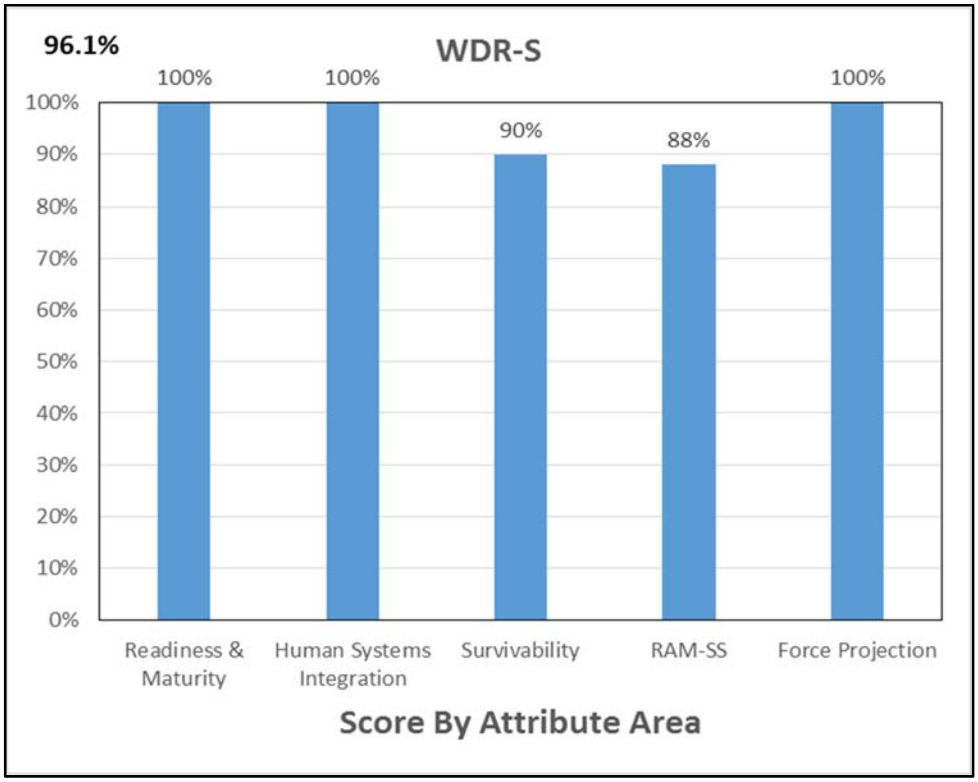

Figure 58: Technology Assessment Graph for the WDR-S

Readiness and Maturity: The low-flow shower head is a COTS item and is fully mature.

Human Systems Integration: COTS item, no HSI issues.

Survivability: COTS item.

RAM-SS: COTS item, no supportability issues.

Force Projection: Identical to the baseline system.

3.4 Waste Reduction

Table 12 contains a list of the technologies examined for potential waste reduction.

Table 12: Waste Reduction - Technologies

ID	Technology/Component	Lab/ RDEC
EE-0920	Solid Waste Destruction System – Altex Technology Corp (SWDS-A)	NSRDEC
EE-0940	Battalion Waste-to-Energy Converter (WEC)	NSRDEC
EE-0980	Wastewater Treatment – Biological (WWT-Bio)	TARDEC
EE-1110	Sustainable Technologies for Ration Packaging Systems (STRPS)	NSRDEC
EE-1140	Ration Packaging Reconfiguration (RPR)	NSRDEC
EE-1230	Low-Cost TRICON Latrine (LCTL)	NSRDEC

3.4.1 Solid Waste Destruction System – Altex Technology Corp (SWDS-A)

3.4.1.1 System Description

The SWDS (**Figure 59**) is a SBIR-funded project to develop a practical and efficient system for onsite disposal of the solid waste generated by small contingency bases of 150-300 persons. Significant features of the SWDS are:

- Rotary pyrolysis plus gasification and self-powered combustion
- Throughput of up to ½ ton/day
- Benign residuals and emissions
- Minimal manpower including operation and waste sorting

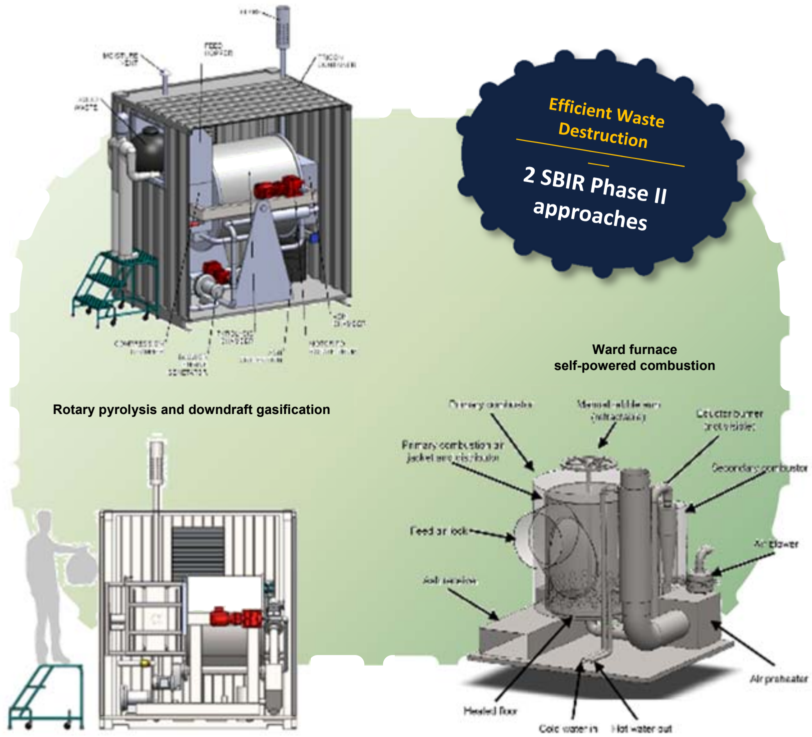

Figure 59: Solid Waste Destruction System

The benefits and payoffs of the SWDS are:

- Reduces logistics in terms of backhauled waste
- Reduces fuel consumption as compared to incinerators and burn pits
- Reduces combustible solid waste by 90% (600 lb of waste would be reduced to less than 60 lb of char and ash)

The SWDS is at TRL 5 and scheduled to transition to PdM-FSS and/or Joint Deployable Waste-to-Energy (JDW2E) effort in FY17.

Technical POC: Leigh Knowlton, NSRDEC, leigh.a.knowlton.civ@mail.mil, 508-233-5183.

3.4.1.2 Technology Assessment

Figure 60 contains the Technology Assessment scoring information for the SWDS-A.

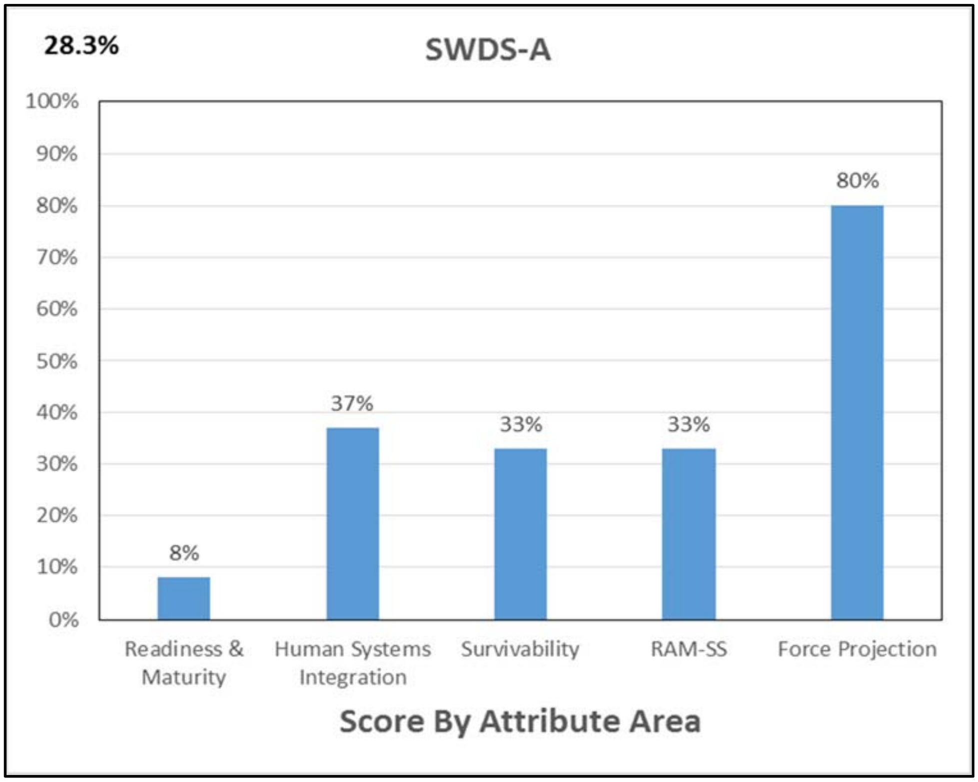

Figure 60: Technology Assessment Graph for the SWDS-A

Readiness and Maturity: Met its performance goals for the SBIR, but requires more R&D to meet Force Provider goals.

Human Systems Integration: System is not overly complex. Safety would be a concern with regard to unsuitable feedstock, e.g., batteries, unspent ammunition, etc.

Survivability: Like many base camp facilities, this system is TRICON-based, offering some military hardening.

RAM-SS: The system is not mature enough to assess these attributes. More evaluation is required.

Force Projection: TRICON-based system.

3.4.2 Battalion Waste-to-Energy Converter (WEC)

3.4.2.1 System Description

The WEC (**Figure 61**) is a system that converts solid waste into a fuel gas that is used in generators to produce electricity. The WEC technology is suitable for the generation of electricity in large Combat Outposts and/or small Forward Operating Bases.

Significant attributes of the WEC are:

- Processes 2 tons per day of mixed non-hazardous solid waste
- Packaged in 20 ft ISO containers for deployability
- Includes power generation for net energy export
- Automatic control and operations with minimal manpower required
- Benign residuals and emissions

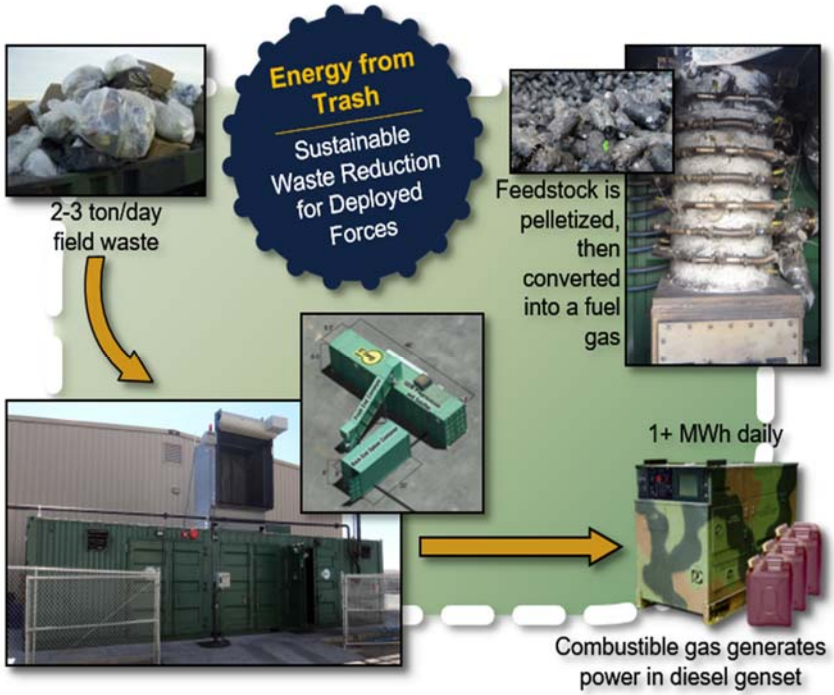

Figure 61: Battalion Waste-to-Energy Converter

The benefits and payoffs of the WEC are:

- Reduced logistic burden of contingency basing in terms of backhauled waste
- Reduces two costly burdens — waste and fuel — which translates to fewer trucks on the road and reduced threat exposure hours for Soldiers
- Reduces carbonaceous solid waste by 95% (4000 lb would be reduced to 200 lb of char and ash)
- Exports electric power (4000 lb yields > 1 MWhe (megawatt-hour of electricity))

The WEC is at TRL 6 and the transition to PdM-FSS and/or the JDW2E effort is pending.

Technical POC: Leigh Knowlton, NSRDEC, leigh.a.knowlton.civ@mail.mil, 508-233-5183.

3.4.2.2 Technology Assessment

Figure 62 contains the Technology Assessment scoring information for the WEC.

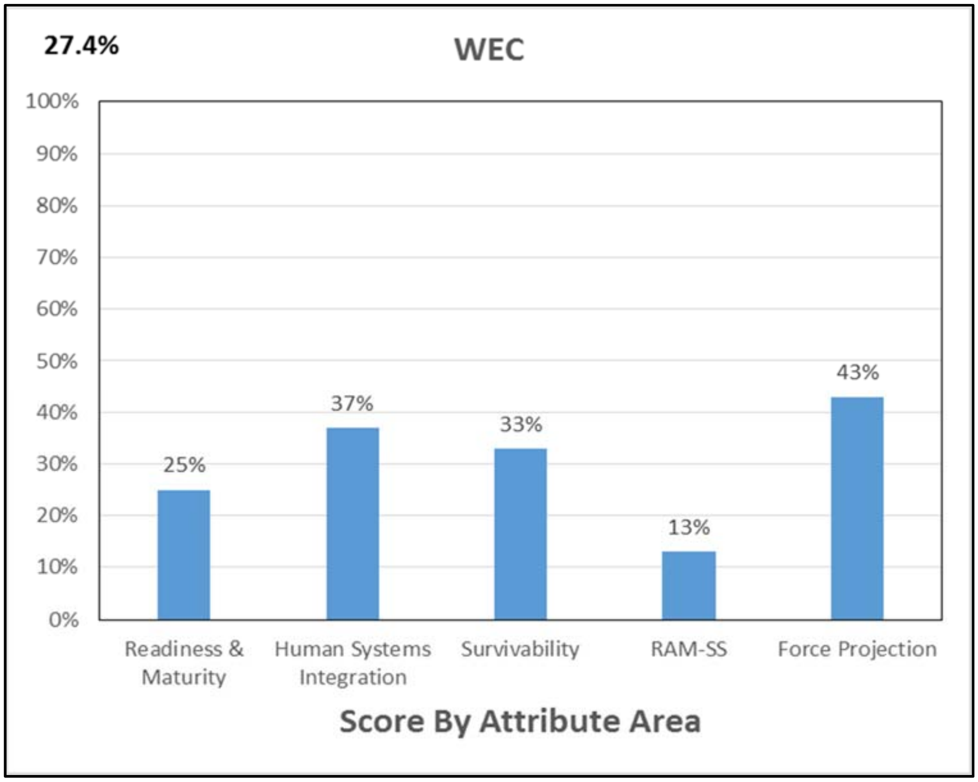

Figure 62: Technology Assessment Graph for the WEC

Readiness and Maturity: Little to no standardization with respect to parts and supplies already in the Army supply chain. However, many major subsystems (shredder, drier, destoner, pelletizer, gas filtration, and power generator) are COTS or COTS-based systems. Control system requires more development for stand-alone unattended operation.

Human Systems Integration: Operation is simple, but maintenance could be complex and will require support via the Logistics Civil Augmentation Program.

Survivability: Not expected to degrade base camp or Soldier survivability.

RAM-SS: The system is not mature enough to assess the RAM parameters.

Force Projection: Deployability and transportability should not be an issue since the system is packaged in standard containers. The system will require significant footprint and access to the camp grid for shuttling produced energy.

3.4.3 Wastewater Treatment - Biological (WWT-Bio)

3.4.3.1 System Description

The WWT-Bio (**Figure 63**) is a stand-alone, biological-based system designed to provide wastewater treatment capabilities at contingency bases to reduce wastewater hauling. Treatment of wastewater to meet Environmental Protection Agency (EPA) secondary treatment standards will allow for safe onsite discharge and a 50%+ reduction in wastewater hauling requirements. The system provides a new capability that is designed to adapt to widely varying load conditions and provide rapid start-up. It reduces the logistics burden and health risk to the camp occupants.

Figure 63: Wastewater Treatment-Biological

System characteristics are:

- Weight: ≤ 7,110 lb
- Size: Pack out volume of ≤ 416 ft^3 (TRICON)
- Manpower is minimal; features automatic control and operation

The WWT-Bio is currently at TRL 6 and is endorsed by PdM-FSS and PdM-PAWS with transition pending.

Technical POC: Lateefah C. Brooks, lateefah.c.brooks.civ@mail.mil, 586-282-6587.

3.4.3.2 Technology Assessment

Figure 64 contains the Technology Assessment scoring information for the WWT-Bio.

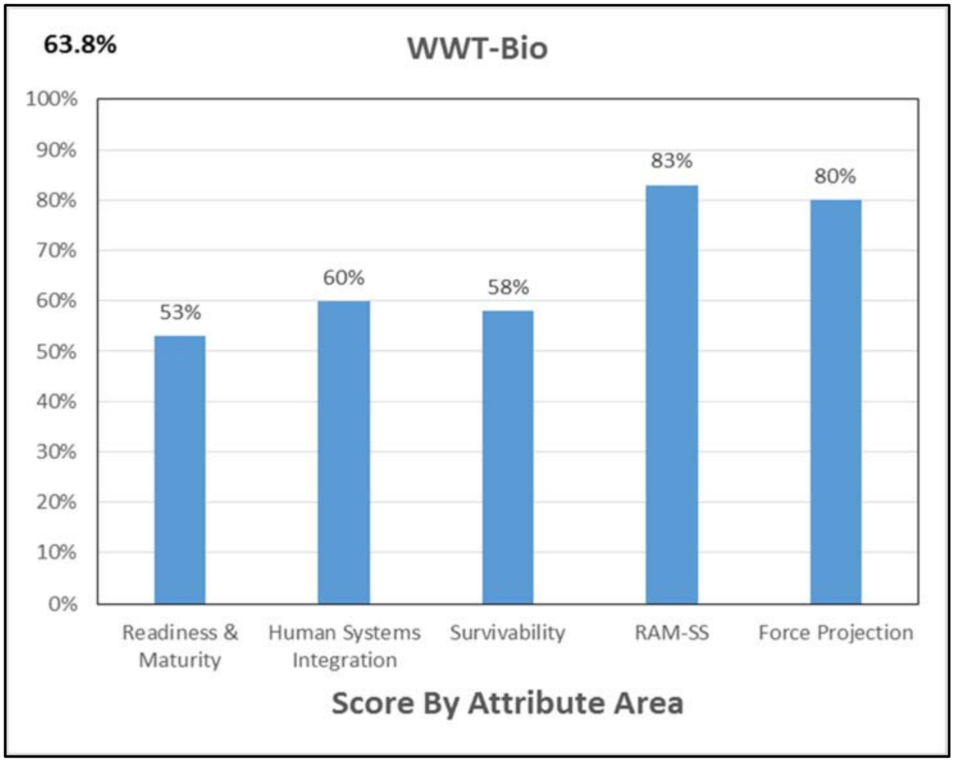

Figure 64: Technology Assessment Graph for the WWT-Bio

Readiness and Maturity: This system has been extensively demonstrated in field environments - Fort Leonard Wood, Fort Bliss, and Fort Devens. The next version of this system should use standard power connections.

Human Systems Integration: The system is not overly complex. No new MOS is required. Should be operated and maintained by Soldiers with MOS 92W (Water Treatment Specialist) or 68S (Preventative Medicine Specialist).

Survivability: The system is fairly rugged. However, the ultraviolet light used for sterilization is somewhat fragile.

RAM-SS: The system should be highly reliable and able to operate continuously. It should be easy to maintain.

Force Projection: The system is deployable and transportable. Planning must consider movement of blackwater to the system and the disposition and use of product water – lagoon, leach field, backhaul, dust abatement, etc.

3.4.4 Sustainable Technologies for Ration Packaging Systems (STRPS)

3.4.4.1 System Description

STRPS (**Figure 65**) is a sustainable materials alternatives program for secondary and unit load-level ration packaging systems to reduce weight, waste, environmental footprint, logistics costs, and use of petroleum-based plastics.

The most significant capabilities developed by STRPS are:

- Straps, pallet wraps, and pallets with bio-based, biodegradable, recyclable, compostable, and/or decreased material usage

The payoff of the program is the development and efficient ration packaging system that reduces logistical burden on the warfighters and minimizes negative impact on the environment.

The STRPS technology is currently at TRL 6 and transition to a Program of Record is pending.

Figure 65: STRPS

Technical POC: Dr. Jo Ann Ratto-Ross, NSRDEC, joann.r.ross.civ@mail.mil, 508-233-5315.

3.4.4.2 Technology Assessment

Figure 66 contains the Technology Assessment scoring information for the STRPS.

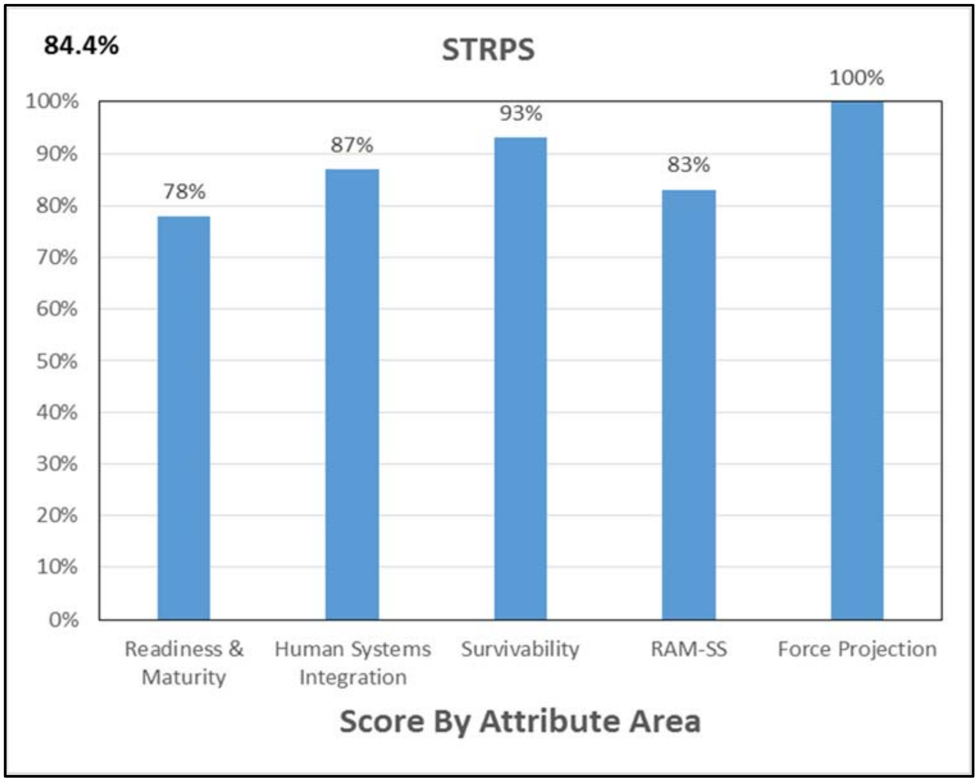

Figure 66: Technology Assessment Graph for the WWT-Bio

Readiness and Maturity: The paper straps for the coated Meal, Ready-to-Eat (MREs) cases have been demonstrated with testing at the Logistics Support Activity, Tobyhanna, PA. The corrugated pallets and the biodegradable stretch wrap were "No Go" in this Combat Feeding Research and Engineering Program.

Human Systems Integration: No issues.

Survivability: The survivability will be the same as the current straps.

RAM-SS: Reliability parameters are the same as current straps. No maintenance or support is required.

Force Projection: Deployability and transportability are the same as the current straps.

3.4.5 Ration Packaging Reconfiguration (RPR)

3.4.5.1 System Description

The RPR project **(Figure 67, legacy left, RPR right)** aims to develop packaging for the MRE case and individual ration that will reduce logistics footprint, use less material during production, and that will produce less waste after consumption.

Significant results and products are:

Figure 67: Comparison of MRE Containers

- Redesigned coated corrugated fiberboard case structure to include materials that are capable of being recycled and do not include harmful additives. Case design will also be considerably lighter, reducing the amount of waste generated from using the system.
- Redesigned individual MRE meal bag packaging to include a thermoformed bag that occupies less space in the box. This will use less material for each MRE, which will reduce material used, reduce waste, and allow for the same number of rations to be packed into a smaller box.

Demonstration of the above capabilities and products will provide:

- Improved shipping logistics from reduced fuel costs and space saved
- Reduction in solid waste generated from MRE system

This technology project is currently at TRL 6 and transition to Program of Record is pending.

Technical POC: Corey Hauver, NSRDEC, corey.d.hauver.civ@mail.mil, 508-233-5315.

3.4.5.2 Technology Assessment

Figure 68 contains the Technology Assessment scoring information for the RPR.

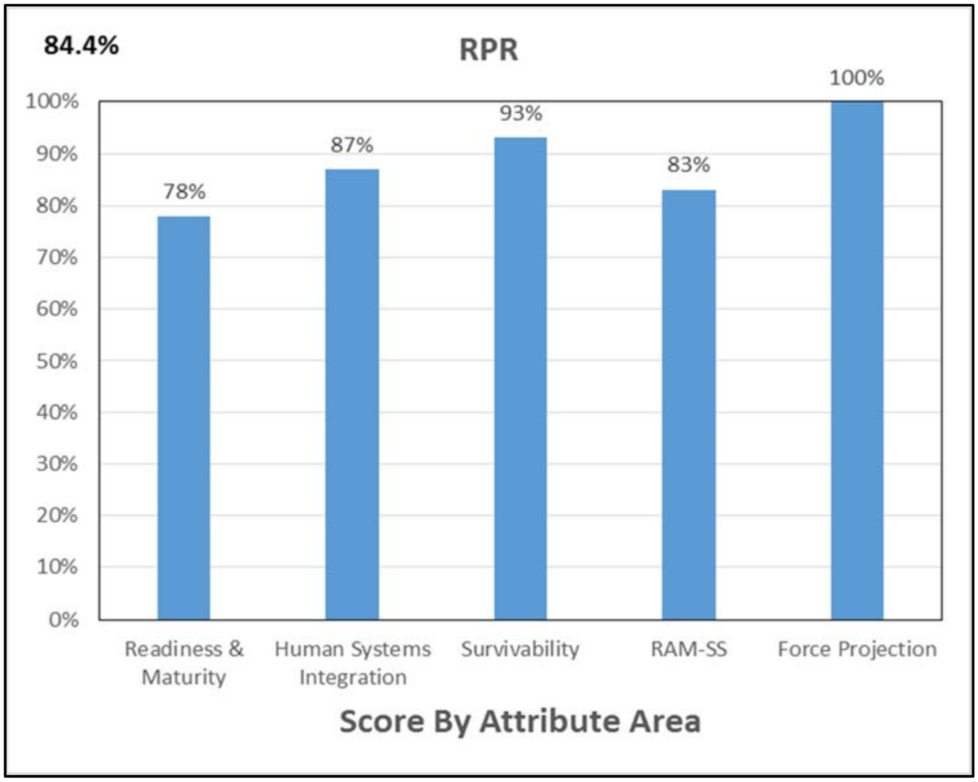

Figure 68: Technology Assessment Graph for the RPR

Readiness and Maturity: Thermoformed meal bags and coated corrugated fiberboard are manufactured from commercially available components (e.g., polymeric film and corrugated fiberboard), and utilize film from Phoenix Chemical Inc. and coated paper from Spectra-Kote Corporation. The thermoformed bags can be made at AmeriQual and the fiberboard containers can be made at most corrugators as long as they accept the coated paper (i.e., York Containers).

Human Systems Integration: No issues.

Survivability: The survivability will be the same as the current ration packaging.

RAM-SS: These items will have the same performance as the existing packaging and are reliable for the warfighter to receive safe food. No maintenance or support is required.

Force Projection: Reduced weight of packaging will enhance the deployability, transportability, and footprint of MREs.

3.4.6 Low-Cost TRICON Latrine (LCTL)

3.4.6.1 System Description

The LCTL (**Figure 69**) is a technology development under the Expeditionary Black Waste Treatment Technologies project. This project endeavors to develop a low maintenance, low power, and low water demand black waste treatment system for expeditionary combat outposts

that improves hygiene and habitability and lowers logistical burden through reductions in water, fuel, and backhaul of waste. The LCTL consists of a single toilet prototype incorporating solid waste processing, incineration, and liquid disinfection.

Figure 69: Low Cost TRICON Latrine

The LCTL provides the following benefits:

- Reduced waste effluent and backhaul of waste
- Fuel and water demand savings
- Improved hygiene, habitability, and Soldier health
- Reduction in personnel involved in removal and disposal of waste

The LCTL is currently at TRL 6 and transition to a Program of Record is pending.

Technical POC: Chris Aall, NSRDEC, christian.d.aall.civ@mail.mil, 508-233-5188.

3.4.6.2 Technology Assessment

Figure 70 contains the Technology Assessment scoring information for the LCTL.

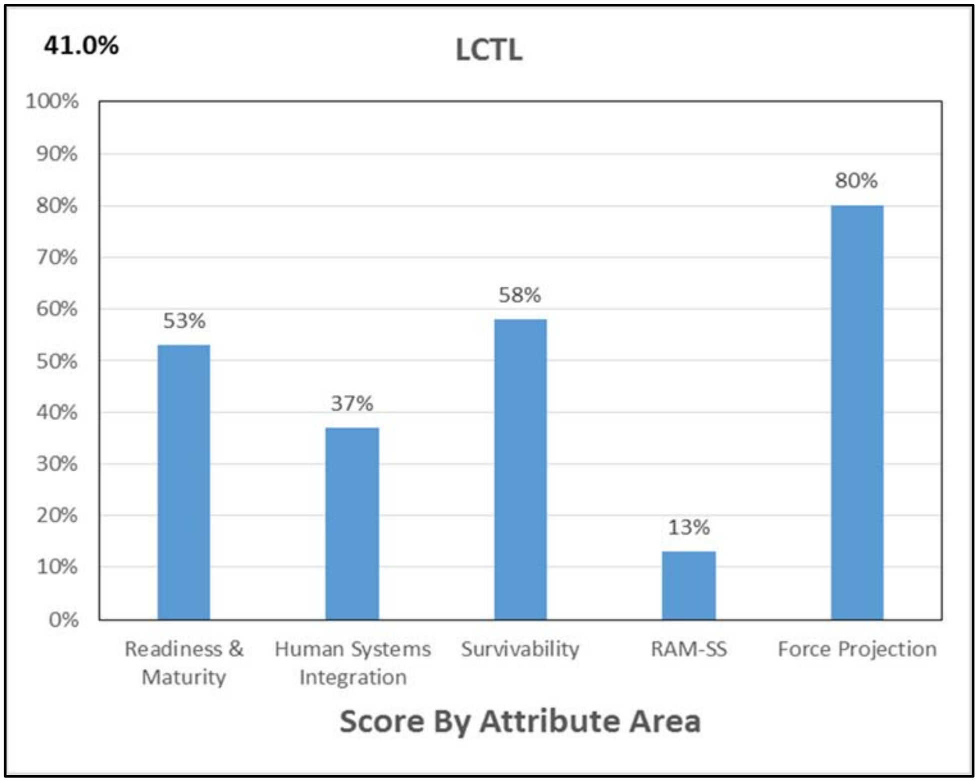

Figure 70: Technology Assessment Graph for the LCTL

Readiness and Maturity: Must be scaled to the waste throughput requirement. Modularity is dependent on the type of system built. A decentralized latrine system must be built with the specific number of commodes and resulting throughput. Intent is for centralized latrine system to support a 150-man camp. Needs further testing through extended deployments.

Human Systems Integration: Net reduction in manpower, due to reduction in waste backhaul activities, though additional manpower required for maintenance.

Survivability: Will be housed in a ruggedized container similar to other base camp structures.

RAM-SS: RAM parameters are unknown at this stage in development.

Force Projection: There are no issues with force projection. Will ship in the same manner and footprint as current latrine systems.

3.5 Quality of Life

Table 13 contains a list of the technologies examined for potential quality of life improvements.

Table 13: Quality of Life - Technologies

ID	Technology/Component	Lab/ RDEC
EE-0685	Onsite Automatic Chiller for Individual Sustainment (OACIS)	NSRDEC
EE-0690	Containerized Ice Making Technologies (CIMT)	NSRDEC
	Containerized Ice Making System (CIMS)	PM E2S2

3.5.1 Onsite Automatic Chiller for Individual Sustainment (OACIS)

3.5.1.1 System Description

The OACIS (**Figure 71**) is a bottled water distribution system that efficiently transports, chills, stores, and dispenses bottled water to the Soldiers. It uses advanced, high-efficiency vapor compression refrigeration to cool up to 1500 bottles per day to 60 °F in 135 °F ambient temperature.

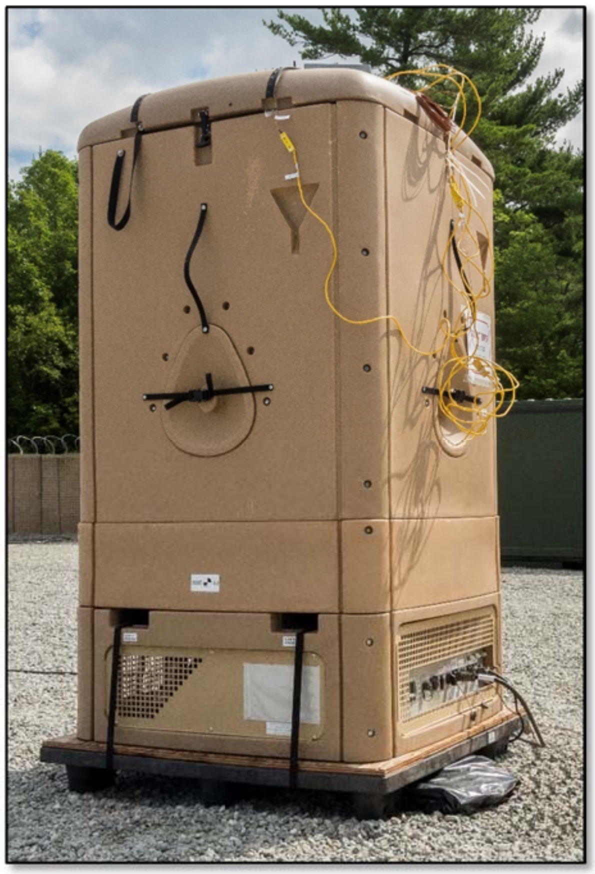

Figure 71: Onsite Automatic Chiller for Individual Sustainment

The OACIS aims to prevent heat illnesses by encouraging hydration with cool water, which is known to be more palatable and assists in cooling down core body temperature during rigorous physical exertion. Heat illnesses and dehydration can significantly degrade the physical performance of Soldiers with a concomitant deleterious effect on mission readiness.

Other features of the OACIS include:

- Uses significantly less energy to cool and store water, especially if solar power is available
- Warfighter hydration status, health and morale — hence readiness — increases with increased availability of chilled bottled water throughout base camps
- Dispenses individual bottles of variable sizes
- Holds 500 L

The OACIS is currently at TRL 6 and transition is pending.

Technical POC: Alexander J. Schmidt, NSRDEC, alexander.j.schmidt4.civ@mail.mil, 508-233-4244.

3.5.1.2 Technology Assessment

Figure 72 contains the Technology Assessment scoring information for the OACIS.

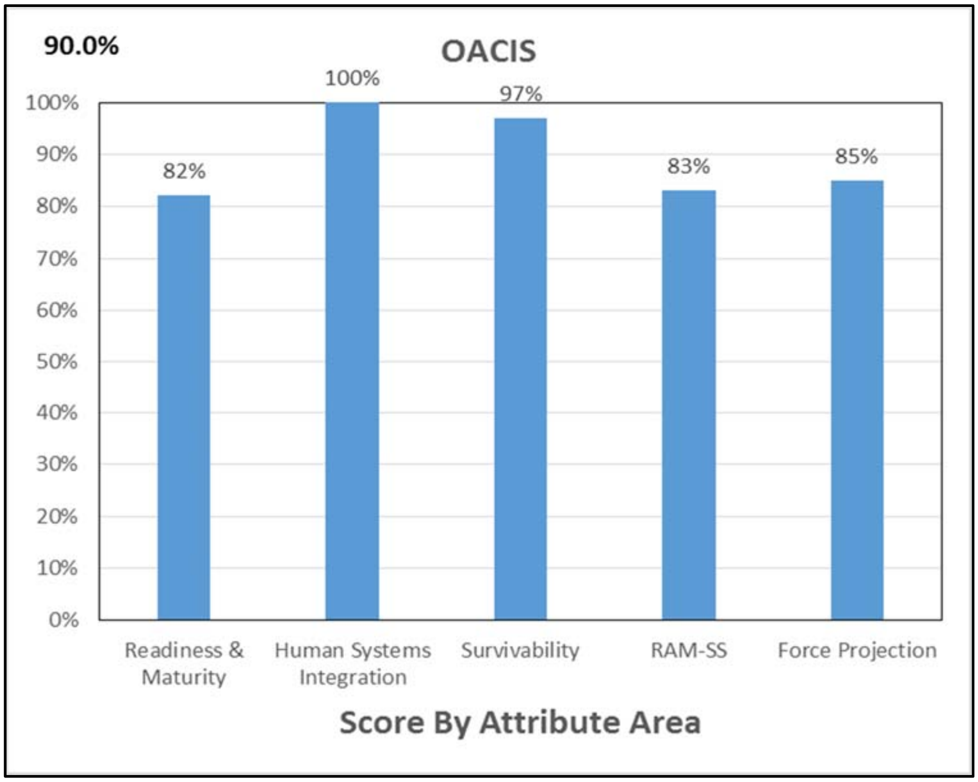

Figure 72: Technology Assessment Graph for the OACIS

Readiness and Maturity: The OACIS performed well at the demonstration.

Human Systems Integration: The only HSI anomaly identified at demonstration concerned loading the unit from the top. This can be awkward for shorter personnel and may require a buddy team and a step-stool or ladder.

Survivability: The unit demonstrated appeared fairly rugged. It is not known how the unit would fare in a CBRN environment. However, some of the contents could be protected from contaminants in that condition.

RAM-SS: Logistics parameters are not yet known. The system is a fairly simple design and would likely score well in RAM testing. No supportability or sustainability issues were identified during demonstration.

Force Projection: This system would be additional equipment for the unit. If desired to deploy, deployment and transportation assets would have to be dedicated and space in the base camp allotted.

3.5.2 Containerized Ice Making Technologies (CIMT)

3.5.2.1 System Description

The goal of the CIMT **(Figure 73)** project is to develop advanced technologies for containerized ice machines that will have greater capability and use less fuel compared to the current deployed systems and near-term solutions. The CIMT consisted of the following components and modules (**Figure 74**): TRICON, compressor and evaporator, condenser, ice maker, ice bagger, ice screw conveyor, and refrigerated ice storage compartment.

Figure 73: Containerized Ice Making Technologies

The CIMT's new capabilities as compared to existing ice making systems are:

- Suitability to hot/dusty/outdoor environments
- Greater ice production rate
- Mobility/transportability
- Modularity
- Compatibility with alternative sources of energy and smart grids

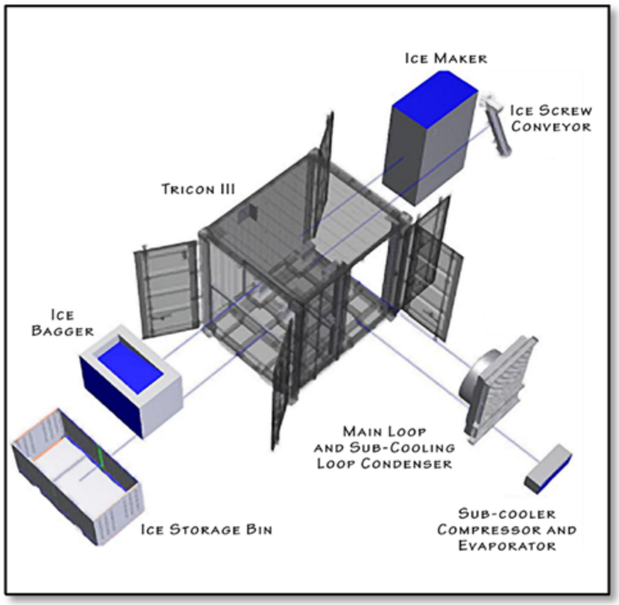

Figure 74: CIMT Components/Modules

The following products and capabilities were demonstrated:

- 1st-generation CIMT prototype
- TRICON-containerized
- 6,900 lb
- Estimated production cost of $100K
- 3,600 lb per day production rate
- Automatic bagging
- 1,200 lb of onboard storage

The CIMT prototype is currently at TRL 5, having been validated in a relevant environment. It is currently scheduled for transition to PdM-FSS at TRL 7.

Technical POC: Alexander J. Schmidt, NSRDEC, alexander.j.schmidt4.civ@mail, 508-233-4244.

3.5.2.2 Technology Assessment

Figure 75 contains the Technology Assessment scoring information for the CIMT.

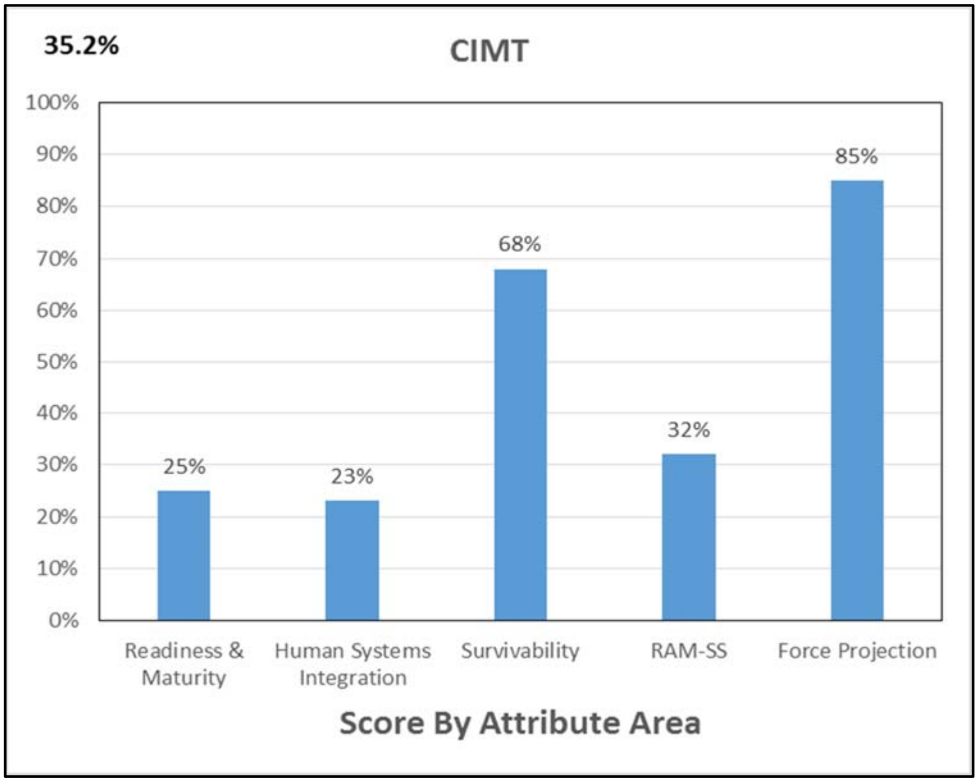

Figure 75: Technology Assessment Graph for the CIMT

Readiness and Maturity: The unit demonstrated in June 2016 at the BCIL needs further fine tuning. That system required near constant vigilance by the vendor to make sure it continued to operate properly. A second unit from a different vendor is scheduled for testing in the first quarter of FY18.

Human Systems Integration: Both systems will require some manpower to operate and maintain. Removing the bagged ice, while straightforward, will need dedicated manpower if the system is expected to operate continuously.

Survivability: The system is housed in a TRICON container. There are no known degraded modes.

RAM-SS: Maintainability of the bagger is a concern. This is the most mechanically challenging of the system operational requirements.

Force Projection: The system is housed in a TRICON container, making deployability and transportability the same as many other camp facilities. Footprint, power, and a potable water source must be dedicated to the system in the camp.

3.5.3 Containerized Ice Making System (CIMS)

3.5.3.1 System Description

The CIMS program will develop the capability to reduce the waste of water and fuel, and decrease the logistics burden by creating an organic ice making system. The CIMS development program will require the following capabilities:

- Produce 3600 lb/day of ice in hot ambient conditions
- Automatically bag cubed ice in sealed 10-lb bags
- Capacity to store 8 h of ice production
- The system shall be no larger than 20 ft x 8 ft x 8 ft and weigh no more than 10,000 lb

The above capabilities and products will provide:

- Reduced waste of water by product, i.e., ice, lost during shipments
- Reduced fuel waste by minimizing the amount of convoys and "trucks on the road" conducting ice deliveries
- Cost savings of producing ice where it is needed vs. shipping ice into theatre
- Reduce logistics support, which saves on product waste, fuel, and personnel resources
- Increased Soldier morale

There are currently multiple CIMS technology demonstrators, as shown in Figures 76-78:

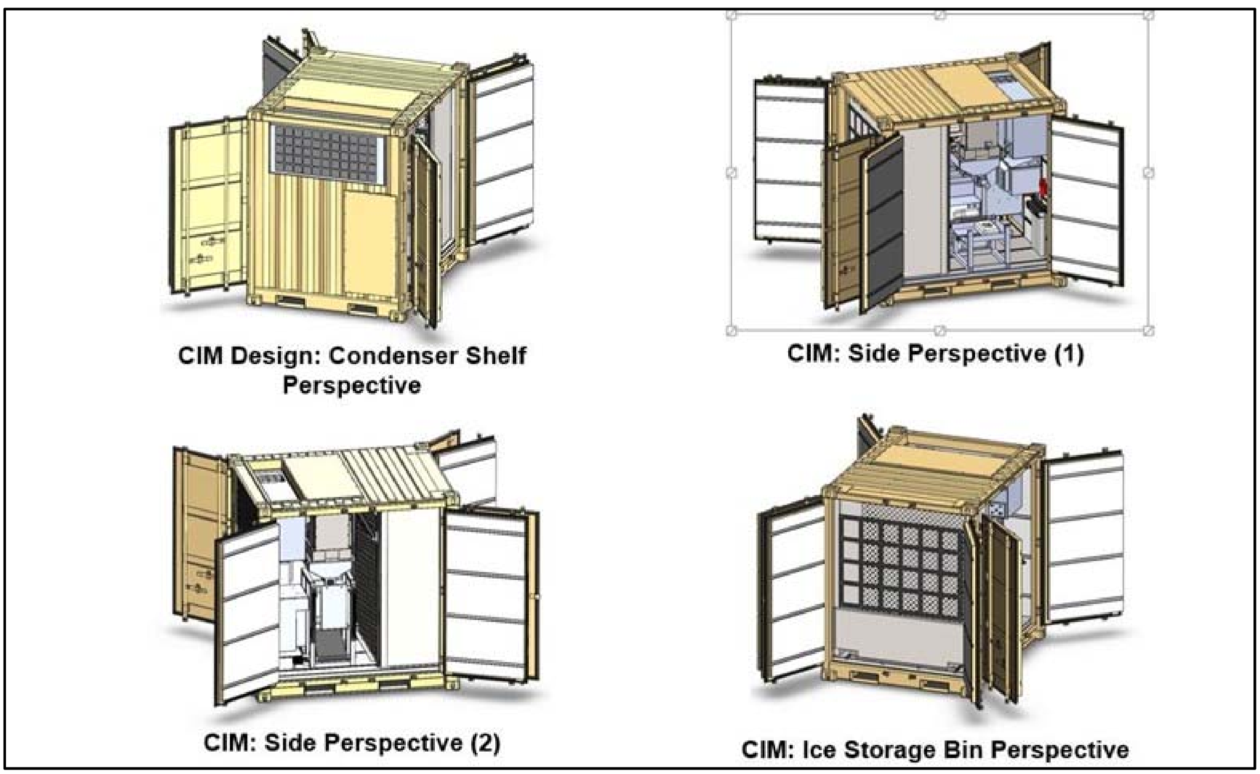

Figure 76: Rocky Research TRICON CIMS

Figure 77: DRS TRICON CIMS

Figure 78: Eco-Ice 20 ft CIMS

Technical POC: William Feather, PM E2S2, william.m.feather.civ@mail.mil, 508-233-4673.

3.5.3.2 Technology Assessment

> NOTE: The CIMS was not demonstrated by the SLB-STO-D. Therefore, there are no assigned scores to analyze. Anecdotal information on attribute categories provided by the POC is recorded below.

Readiness and Maturity: Multiple vendors have produced developmental systems for testing and demonstration. Limited performance and durability testing has been completed on three different systems, while one system is still undergoing test. A production contract award is expected in 1QFY19.

Human Systems Integration: The system should require little attention. Soldier interaction should be limited to removing product and replacing ice storage bags.

Survivability: This system will require additional testing under various conditions.

RAM-SS: No system has undergone true reliability testing. Evaluation is scheduled.

Force Projection: This system will be a standard 20 ft or TRICON-sized container. It will be easily transportable and deployable.

4. SUMMARY AND CONCLUSION

As part of the SLB-STO-D's capstone effort, the EDVT was directed to conduct a Selected Technology Assessment of the systems down-selected into the Integrated Solution Sets. These systems showed great promise in demonstration, modeling, and simulation of contingency base camps to contribute to the reduction of fuel resupply by 25%, water resupply by 75%, and waste generated for backhaul by 50%, while maintaining a Force Provider-like QoL (O).

The EDVT developed a deliberate step-wise process to execute this task. The steps included identifying and defining the attributes, collecting attribute data from Technology Providers, developing value curves for attributes, then scoring the attributes and conducting the analysis. The CLT and the EDVT met with each RDEC in turn at their locations. The Technology Providers did an excellent job providing data for system attributes. The MSBL at MSCoE developed and executed the scoring protocols and analysis. The output of this analysis consists of the results reported in Chapter 3, supported by the data cataloged in Annex B. This information can be useful for both Materiel Developers and Capability Developers.

For Materiel Developers, this assessment of R&D technologies has identified some areas that indicate promise and some areas that indicate more work is required. The selected technologies are at various stages in their developmental cycle. Through field demonstration and this assessment, the SLB-STO-D has helped identify what works well, and some features that do not yet work as well as desired. Materiel Developers can use this information to focus efforts and aid in funding decisions. Some of the technologies featured in the ISS are funded for further development while some are not. Many of the systems have in place technology transition plans, but some do not, where perhaps they should.

For Capability Developers, this assessment may assist with requirements generation, training development, and base camp doctrine, e.g., base camp design considerations. The system attribute data gives clues to TRADOC agencies and Combatant Commanders for future DOTMLPF considerations related to contingency base camp planning and execution.

The method developed for this assessment can be repeated for any similar project. The chosen attributes can be adjusted based on the scope and needs of the project.

This document reports research undertaken at the U.S. Army Natick Soldier Research, Development and Engineering Center, Natick, MA, and has been assigned No. NATICK/TR- 18/005 in a series of reports approved for publication.

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LIST OF ACRONYMS

AAR	After Action Review
AR	Army Regulation
ARCIC	Army Capabilities Integration Center
ARDEC	U.S. Army Armament Research, Development and Engineering Center
ATEC	Army Test and Evaluation Command
ATP	Army Techniques Publication
BAH	Booz, Allen, Hamilton
BCIL	Base Camp Integration Laboratory
B-Hut	Barracks Hut
BOS	Balance of Systems
BTU	British thermal unit
CASCOM	Combined Arms Support Command
CB-EMS	Contingency Base-Energy Management System
CBITEC	Contingency Basing Integration and Technology Evaluation Center
CBRN	Chemical, Biological, Radiological and Nuclear
CBUS	Contingency Basing Utilities System
CDD	Capability Development Document
CERDEC	U.S. Army Communications-Electronics Research, Development and Engineering Center
CERL	Construction Engineering Research Laboratory
CIMS	Containerized Ice Making System
CIMT	Containerized Ice Making Technologies
CLT	Core Leadership Team
COB	Contingency Operating Base
COP	Combat Outpost
COTS	Commercial Off-the-Shelf
CPD	Capability Production Document
DAG	Data Authentication Group
DAU	Defense Acquisition University
dBBR	Deployable Baffled Bioreactor (see also WWT-Bio)
DESERT	Desert Environment Sustainable Efficient Refrigeration Technology

DFAC	Dining Facility
DIACAP	DoD Information Assurance Certification and Accreditation Process
DMMS	Deployable Metering and Monitoring System
DoD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities
DP2	DESERT Power 2
ECU	Environmental Control Unit
EDVT	Experimentation, Demonstration, and Validation Team
EIO-C	Energy Informed Operations-Central
EPA	Environmental Protection Agency
ERDC	U.S. Army Engineering Research and Development Center
FF-ETK	Expeditionary TRICON Kitchen System Appliance, Fuel-Fired
FOB	Forward Operating Base
FORO	Forward Osmosis/Reverse Osmosis
FPE	Force Provider Expeditionary
FWW	Fuel, Water, Waste
FY	Fiscal Year
GDIT	General Dynamics Information Technology
G-WTRS	Efficient Water Reuse Technologies for COBs (informally, Graywater Treatment and Reuse System)
HDT-42K	HDT 42K BTU Environmental Control Unit
HEMP	High-altitude Electromagnetic Pulse
HERU	High-efficiency Refrigeration Unit
HFE	Human Factors Engineering
HMMWV	High Mobility, Multipurpose Wheeled Vehicle
HPT	Hybrid Power Trailer
HSI	Human Systems Integration
IPD	Intelligent Power Distribution
ISO	International Organization for Standardization
ISS	Integrated Solution Set
JDW2E	Joint Deployable Waste-to-Energy
JP-8	Jet Propulsion Fuel Type 8
KPP	Key Performance Parameter

LCTL	Low Cost TRICON Latrine
LED	Light-emitting Diode
LINER	Energy Efficient Expedient Shelters with Non-woven Composite Insulation Liners
MACK	Modular Appliance for Configurable Kitchens
MANGEN	Man-portable Genset for Power Generation for Expeditionary Small Unit Operations
MBSE	Model-Based Systems Engineering
MIL-STD	Military Standard
MOS	Military Occupational Specialty
MRE	Meal, Ready-to-Eat
MSAT	Modeling, Simulation, and Analysis Team
MSBL	Maneuver Support Battle Lab
MSCoE	Maneuver Support Center of Excellence
MTBEFF	Mean Time Between Essential Function Failures
MTBF	Mean Time Between Failures
MTRCS	Multi-Temperature Refrigerated Container System
MTTR	Mean Time to Repair
NBC	Nuclear, Biological, Chemical
NCO	Non-Commissioned Officer
NMS	Non-materiel Solution
NSN	National Stock Number
NSRDEC	U.S. Army Natick Soldier Research, Development and Engineering Center
OACIS	Onsite Automatic Chiller for Individual Sustainment
OE	Operational Energy
ORTB	Operationally Relevant Technical Baseline
PD CBI	Product Director, Contingency Basing Infrastructure
PdM-FSS	Product Manager, Force Sustainment Systems
PdM-PAWS	Product Manager, Petroleum and Water Systems
PF	Power Factor
PM	Program Manager
PM E2S2	Project Manager, Expeditionary Energy & Sustainment System
POC	Point of Contact

POL	Petroleum, Oil, and Lubricants
POR	Program of Record
PSHADE	PowerShade Cost Reduction
PV	Photovoltaic
QoL (O)	Quality of Life (Operational)
R&D	research and development
RAM	Reliability, Availability and Maintainability
RAM-SS	Reliability, Availability, Maintainability, Supportability, Sustainability
RDEC	Research, Development and Engineering Center
RDECOM	U.S. Army Research, Development and Engineering Command
RIT	Requirements Integration Team
RPR	Ration Packaging Reconfiguration
SAIC	Science Applications International Corporation
SBIR	Small Business Innovation Research
SCPL	Single Common Powertrain Lubrication
SEIT	Systems Engineering and Integration Team
SFC	Sergeant First Class
SIP-Hut	Structural Insulated Panel Hut
SLB-STO-D	Sustainability Logistics – Basing Science and Technology – Demonstration
SME	Subject Matter Expert
SPSWH	Self-Powered Solar Water Heater
STA	Selected Technology Assessment
STRPS	Sustainable Technologies for Ration Packaging Systems
SWDS	Solid Waste Destruction System
SWDS-A	SWDS – Altex Technology Corp
T100	HMMWV-Towable Load-Following 100 kW Power Unit
TACOM	U.S. Army Tank-automotive and Armaments Command
TARDEC	U.S. Army Tank Automotive Research, Development, and Engineering Center
TCM-MS	TRADOC Capability Manager – Maneuver Support
TECD	Technology-Enabled Capability Demonstration
TEMPER	Tent, Extendable, Modular, Personnel
TMIT	Technology Maturation and Integration Team

TQG	Tactical Quiet Generator
TRADOC	U.S. Army Training and Doctrine Command
TRICON	Triple Container
TRL	Technology Readiness Level
TWPS	Tactical Water Purification System
WATERMON	Real Time Inline Diagnostic Technology (informally, water monitor)
WAVE	Wide Area Visualization Environment
WCT	Water Conservation Technology for Mobile Kitchens and Sanitation Centers
WDR	Water Demand Reduction Technologies
WDR-S	WDR-Showers
WEC	Battalion Waste-to-Energy Converter
WFA	Modular Force Water Generation Storage & Analysis (also, Water from Air)
WWT-Bio	Wastewater Treatment-Biological (also called the dBBR by the vendor)

ANNEX A – CATALOG OF ATTRIBUTE DEFINITIONS

A.1 Readiness and Maturity

A.1.1 Technology Readiness Level

Function	Readiness and Maturity
ID#	1.1
Attribute	*TRL*
Attribute Source-1	SLB-STO-D strategy
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	TRLs are a measure of technical maturity. (DAG Sec 10.5.2.2) The assessment (for TRLs for all CTEs) will be based on objective evidence gathered during events such as tests, demonstrations, pilots, or physics-based simulations. Based on the requirements, identified capabilities, system architecture, software architecture, CONOPS, and/or the concept of employment, the IRT (Integrated Requirements Team) will define operationally relevant environments and determine which TRL is supported by the objective evidence. (DAG Sec 9.6.1) Technology Readiness Levels (TRLs) can serve as a helpful knowledge-based standard and shorthand for evaluating technology maturity, but they must be supplemented with expert professional judgment. (DAG Sec 10.5.2) Also of interest are Technology Transition Agreements (TTA). Does the system have a TTA?
Comment	TRL assignment is the common method for rating a system's level of readiness and maturity.
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D.

A.1.2 Standardization, Interoperability

Function	Readiness and Maturity
ID#	1.2
Attribute	*Standardization, Interoperability*
Attribute Source-1	ATP 3-37.10
Attribute Source-2	SLB-STO-D strategy
Attribute Source-3	
Attribute Source-4	
Definition	Using standardized, scalable, and adaptable designs and construction, such as those in the AFCS, simplifies construction programming activities, improves early planning, and provides consistency in the application of levels of capabilities and the resultant facilities and QOL on base camps. Standardization is achieved by enforcing base camp standards and guidance articulated in the CCDR's basing strategy, planning guidance, and design guides. The ability of a system (as a weapons system) to work with or use the parts or equipment of another system.
Comment	Standardizing designs and construction throughout the operational area eases repair and maintenance efforts by allowing for common stocks of parts and supplies which helps reduce inventories. It also reduces skill or training requirements for maintenance and repair workers. The use of custom-made designs can prove to be more costly and difficult to maintain and repair based on the future availability of parts, materials, and skilled labor needed. Therefore, facility and infrastructure designs are based on standard or traditional designs and constructed with standard or stock parts and materials that are readily available locally or through supply channels.
DataSource	Data from Tech Provider; supported by SEIT; scored by SMEs.

A.1.3 Tailorability, Modularity, Versatility, Scalability

Function	Readiness and Maturity
ID#	1.3
Attribute	*Tailorability, Modularity, Versatility, Scalability*
Attribute Source-1	MSCoE CDD
Attribute Source-2	FP CPD
Attribute Source-3	ATP 3-37.10
Attribute Source-4	
Definition	Use modular and multifunctional designs. Use modular buildings and trailer units that can be relocated, repositioned, and reused (or easily dismantled) and offer flexibility. Create designs that allow the base camp to easily expand or contract size and levels of service.
Comment	1-44. Contingency operations are inherently uncertain. The size, composition, and positioning of forces are continuously adjusted based on mission requirements. Base camps must be able to accommodate these often unpredictable demands and remain responsive to the commander's needs. Scalability is the ability to tolerate population fluctuations and incorporate changes in the level of capabilities without the need for redesign. Solutions remain efficient and practical whether a base camp becomes larger or smaller. 1-45. Base camp facilities and infrastructure must be scalable to equally handle both increases and decreases in their population with the least amount of resources and effort. This is especially important during transitions in support of base camp closures and realignments, and transfers of authority when base camp populations are essentially doubled. 1-46. Base camp plans, designs, materials, components, systems, construction methods, operational staffs, and communications systems should all be modular and scalable. Comprehensive scalable base camp solutions are integrated and developed at the joint and Service levels.
DataSource	Data from Tech Provider; supported by SEIT; scored by SMEs.

A.1.4 Net Ready

Function	Readiness and Maturity
ID#	1.4
Attribute	*Net Ready*
Attribute Source-1	Req'd KPPs
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	NR KPP is to ensure new Information Systems (IS) fit into the existing DoD architectures and infrastructure to the maximum extent practicable. For additional guidance, see Appendix E to Enclosure D of the JCIDS manual. The NR-KPP identifies operational, net-centric requirements in terms of threshold and objective values for measures of effectiveness (MOEs) and measures of performance (MOPs). The NR KPP covers all communication, computing, and electromagnetic spectrum requirements involving information elements among producer, sender, receiver, and consumer. Information elements include the information, product, and service exchanges. These exchanges enable successful completion of the warfighter mission or joint business processes. The NR-KPP includes three attributes derived through a three-step process of mission analysis, information analysis, and systems engineering. These attributes are then documented in solution architectures developed according to the current DoD Architecture Framework (DoDAF). The attributes depict how planned or operational IS: Attribute 1 - Supports military operations, Attribute 2 - IS entered and managed on the network, and Attribute 3 - Effectively exchanges information.
Comment	The Net Ready attribute will be applicable to only a very few of the SLB-STO-D technologies, but is included here since it is a mandatory KPP when developing CDDs.
DataSource	Data from Tech Provider; supported by SEIT; scored by SMEs.

A.2 Human Systems Integration

A.2.1 Manpower

Function	Human Systems Integration
ID#	2.1
Attribute	*Manpower*
Attribute Source-1	HSI (AR 602-2)
Attribute Source-2	SLB-STO-D strategy
Attribute Source-3	
Attribute Source-4	
Definition	The number of military and civilian personnel required, authorized, and potentially available to train, operate, maintain, and support the system. (AR 602-2 para 1-5.b.(1))
Comment	What impact will this technology have on troop-to-task ratio? Does this technology require a full-time operator? Who in the unit will operate and maintain this equipment? How many hours a day?
DataSource	Manpower requirements provided by Tech Provider; assessed by SLB-STO-D and SMEs.

A.2.2 Personnel Capabilities

Function	Human Systems Integration
ID#	2.2
Attribute	*Personnel Capabilities*
Attribute Source-1	HSI (AR 602-2)
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	The human aptitudes, skills, and capabilities required to operate, maintain, and support a system in peacetime and war. (AR 602-2 para 1-5.b.(2))
Comment	Does this system require a new MOS?
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D.

A.2.3 Human Factors Engineering, Complexity

Function	Human Systems Integration
ID#	2.3
Attribute	*HFE, Complexity*
Attribute Source-1	HSI (AR 602-2)
Attribute Source-2	SLB-STO-D strategy
Attribute Source-3	
Attribute Source-4	
Definition	The comprehensive integration of human capabilities and limitations into system definition, design, development, and evaluation to promote effective Soldier-machine integration for optimal total system performance. (AR 602-2 para 1-5.b.(4))
Comment	How complex is this system compared to others of similar capability? What has been done to reduce complexity and improve or simplify the human-machine interface?
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D.

A.2.4 System Safety

Function	Human Systems Integration
ID#	2.4
Attribute	*System Safety*
Attribute Source-1	HSI (AR 602-2)
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	The design and operational characteristics of a system that minimize the possibilities for accidents or mishaps caused by human error or system failure. (AR 602-2 para 1-5.b.(5))
Comment	What hazards to the system must be mitigated?
DataSource	Data from Tech Provider; supported by SEIT; scored by SMEs.

A.2.5 Health Hazards

Function	Human Systems Integration
ID#	2.5
Attribute	*Health Hazards*
Attribute Source-1	HSI (AR 602-2)
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	The systematic application of biomedical knowledge, early in the acquisition process, to identify, assess, and minimize health hazards associated with the system's operation, maintenance, repair, or storage, such as: acoustic energy, toxic substances (biological and chemical), oxygen deficiency, radiation energy, shock, temperature extremes, trauma, and vibration. (AR 602-2 para 1-5.b.(6))
Comment	What hazards to the operator and maintainer must be mitigated?
DataSource	Data from Tech Provider; supported by SEIT; scored by SMEs.

A.2.6 Training

Function	Human Systems Integration
ID#	2.6
Attribute	*Training*
Attribute Source-1	MSCoE CDD
Attribute Source-2	Req'd KPPs
Attribute Source-3	HSI (AR 602-2)
Attribute Source-4	
Definition	When trained to established standards, Soldiers representative of the target audience population with the required critical skills, knowledge and abilities, must be able to perform all critical tasks safely, with no exposure to uncontrolled health hazards. Users shall have the ability to train, operate and maintain the Contingency Basing Utilities System (CBUS). (CBUS working CDD) The instruction and resources required to provide Army personnel with requisite knowledge, skills, and abilities to properly operate, maintain, and support Army systems. (AR 602-2 para 1-5.b.(3))
Comment	All systems will require some level of training or familiarization. For the purposes of the assessment we should consider the level of effort to develop training materials, if required, and the level of effort to train the task. NOTE: A requirement for training is not a negative if the system contributes substantial capability.
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D, scored by SMEs.

A.3 Survivability

Function	Survivability
ID#	3
Attribute	*Survivability*
Attribute Source-1	MSCoE CDD
Attribute Source-2	Req'd KPPs
Attribute Source-3	ATP 3-37.10
Attribute Source-4	
Definition	CBUS system shall provide for and enable operation in degraded EM and cyber environments; and allow the system to survive and continue to operate in, or after exposure to, a CBRN environment. It will also include resiliency attributes pertaining to the ability of the broader architecture to complete the mission despite the loss of individual systems Optimize perimeter zone and entry control point alignment. Provide appropriate spacing between structures. Ensure adequate standoff (position key facilities as far away from the perimeter as possible). Apply hardening where appropriate. Construct a perimeter zone with supporting outer and inner security areas including engagement area development considerations and other appropriate features and systems.
Comment	At a minimum, a selected technology should not degrade base camp or Soldier survivability. Resiliency is an advantage. 1-59. A primary purpose of base camps is providing a protected location from which to project and sustain combat power. Base camps depend on the application of effective protection strategies that is generally achieved by developing a comprehensive protection plan consistent with the principles of protection articulated in ADRP 3-37. Base camps must be equally prepared to protect against the effects of hostile actions, nonhostile activities such as fire, and environmental conditions such as floods and earthquakes.
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D, scored by SMEs.

A.4 Reliability, Maintainability, Availability – Sustainability, Supportability

A.4.1 Reliability

Function	RAM-SS
ID#	4.1
Attribute	*Reliability*
Attribute Source-1	MSCoE CDD
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	Reliability is the probability that an item can perform its intended function for a specified interval under the stated conditions. ("How long will it work?")
Comment	AR 702-19 While systems have not yet entered that part of their life cycle that includes RAM testing, the SLB-STO-D should make qualitative statements, supported by demonstration where possible, about the RAM characteristics of a system.
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D, scored by SMEs.

A.4.2 Availability

Function	RAM-SS
ID#	4.2
Attribute	*Availability*
Attribute Source-1	MSCoE CDD
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	Availability is a measure of the degree to which an item is in the operable and commitable state at the start of a mission when the mission is called for at an unknown (random) time. ("How ready is the system to perform when needed?")
Comment	AR 702-19 While systems have not yet entered that part of their life cycle that includes RAM testing, the SLB-STO-D should make qualitative statements, supported by demonstration where possible, about the RAM characteristics of a system.
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D, scored by SMEs.

A.4.3 Maintainability

Function	RAM-SS
ID#	4.3
Attribute	*Maintainability*
Attribute Source-1	MSCoE CDD
Attribute Source-2	SLB-STO-D strategy
Attribute Source-3	
Attribute Source-4	
Definition	Maintainability is the measure of an item's ability to be retained in or restored to a specified condition when maintenance is performed by skilled personnel, using the correct procedures and resources. ("How long does it take to repair?")
Comment	AR 702-19 While systems have not yet entered that part of their life cycle that includes RAM testing, the SLB-STO-D should make qualitative statements, supported by demonstration where possible, about the RAM characteristics of a system.
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D, scored by SMEs.

A.4.4 Sustainability

Function	RAM-SS
ID#	4.4
Attribute	*Sustainability*
Attribute Source-1	MSCoE CDD
Attribute Source-2	Req'd KPPs
Attribute Source-3	ATP 3-37.10
Attribute Source-4	SLB-STO-D strategy
Definition	1-47. Base camps must be sustainable. This means that base camps achieve and sustain effectiveness within the means of available resources (materials, labor, energy, and funds) and without placing unnecessary strain on existing sustainment systems. Sustainability is primarily achieved through minimizing demand and cost-effective consumption of resources. Although these two methodologies are similar, the former is generally not appropriate for areas such as survivability, health, safety, and other aspects of Soldier/Marine welfare.
Comment	1-48. This principle is broadly aimed at optimizing efficiency in base camps and in no way discounts the overriding requirement for operational effectiveness. This principle acknowledges the importance of ensuring the uninterrupted provision of essential base camp functions through redundancy in systems and protection of critical infrastructure. While the probability of fully incorporating this principle is directly proportional to the expected duration of a base camp (higher probability in longer-duration base camps), it remains important to smaller, shorter-duration base camps since those camps could become long-duration base camps as the operation progresses.
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D, scored by SMEs.

A.4.5 Supportability

Function	RAM-SS
ID#	4.5
Attribute	*Supportability*
Attribute Source-1	MSCoE CDD
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	Supportability is the degree to which system design characteristics and planned logistics resources meet system peacetime readiness and wartime utilization requirements.
Comment	What are the support requirements for this system in terms of expendable supplies, tools, etc.?
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D, scored by SMEs.

A.5 Force Projection

A.5.1 Deployability

Function	Force Projection
ID#	5.1
Attribute	*Deployability*
Attribute Source-1	MSCoE CDD
Attribute Source-2	FP CPD
Attribute Source-3	
Attribute Source-4	
Definition	The Force Provider Expeditionary (FPE) shall be capable of military or commercial transport by highway, rail, sea, or air (T/O).
Comment	For the purposes of this assessment deployability will be thought of as the capability of the system to deploy from home station to operational theater.
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D, scored by SMEs.

A.5.2 Transportability

Function	Force Projection
ID#	5.2
Attribute	*Transportability*
Attribute Source-1	MSCoE CDD
Attribute Source-2	FP CPD
Attribute Source-3	
Attribute Source-4	
Definition	The FPE, less add-on kits, shall achieve a 10% reduction in shipping cube as compared to the legacy (revision B) FP (T), 25% reduction (O).
Comment	For the purposes of this assessment transportability will be thought of as the capability to be transported from the point of debarkation to the contingency base camp where the system will be operated.
DataSource	Assessment by the Technology Provider, assisted by the SLB-STO-D, scored by SMEs.

A.6 Impact of Footprint

Function	Impact of Footprint
ID#	6
Attribute	*Impact of Footprint*
Attribute Source-1	SLB-STO-D strategy
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	The size, shape, weight, and location of a technology can have an impact, positive or negative, on base camp management, operations and security.
Comment	Also, what other systems must the technology be positioned near? Is there room? What planning considerations must be observed to emplace this technology? After the system is set up, are there other storage requirements for parts, accessories, etc.?
DataSource	Data from Tech Provider; supported by SEIT; scored by SMEs.

A.7 Cost/Affordability

Function	Cost/Affordability
ID#	7
Attribute	*Cost/Affordability*
Attribute Source-1	SLB-STO-D strategy
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	Production costs.
Comment	For the purposes of this assessment we will focus on predicted production costs, not R&D. For example, how much will it cost to produce, what are the cost drivers, how will the cost compare to similar items, etc.?
DataSource	Data from Tech Provider; reviewed by SLB-STO-D and SMEs.

A.8 Soldier Feedback

Function	Soldier Feedback
ID#	8
Attribute	*Soldier Feedback*
Attribute Source-1	SLB-STO-D strategy
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	During demonstrations Soldiers have been included in familiarization briefings, training, and in some cases, operation of systems. Soldiers have provided their feedback based on these activities.
Comment	Collate the comments made by Soldiers during focus groups, training, interviews, etc.
DataSource	CRT (EDVT will research previous reports).

A.9 Lessons Learned

Function	Lessons Learned
ID#	9
Attribute	*Lessons Learned*
Attribute Source-1	SLB-STO-D strategy
Attribute Source-2	
Attribute Source-3	
Attribute Source-4	
Definition	Each demonstration included daily reviews of activities and closing After Action Reviews. Technology Providers and SLB-STO-D functional teams discussed lessons learned during these events.
Comment	List the Lessons Learned during demonstration, both positive, negative, and informative.
DataSource	EDVT will review AARs and Lessons Learned submissions.

ANNEX B – SYSTEM ATTRIBUTES OF SELECTED TECHNOLOGIES

Attribute data for each selected technology are documented in this annex. The vast majority of the data were provided by the respective Technology Providers. Soldier feedback comments were generally a direct lift from the reports of the Consumer Research Team published for each demonstration and included in the respective demonstration report. Lessons learned data come from a variety of sources including After Action Reviews (AARs) conducted at demonstration venues, notes from Technology Providers, or input from the demonstration team.

Common acronyms and abbreviations used in the data include:

AMMPS	Advanced Medium Mobile Power Source
BCIL	Base Camp Integration Laboratory
CBITEC	Contingency Basing Integration and Technology Evaluation Center
CBRN	Chemical, Biological, Radiological and Nuclear
CERDEC	Communications-Electronics Research, Development and Engineering Center
COTS	Commercial off-the-shelf
ECU	Environmental Control Unit
EMI	Electromagnetic Interference
ERDC	Engineering Research and Development Center
FOB	Forward Operating Base
HEMP	High-altitude Electromagnetic Pulse
HEMTT	Heavy Expanded Mobility Tactical Truck
HFE	Human Factors Engineering
HMMWV	High Mobility, Multipurpose Wheeled Vehicle
IECU	Improved Environmental Control Unit
ISO	International Organization for Standardization
MOS	Military Occupational Specialty
MTBF	Mean Time Between Failures
NSN	National Stock Number
NSRDEC	Natick Soldier Research, Development and Engineering Center
PDISE	Power Distribution, Illumination System, Electrical
PdM-FSS	Product Manager, Force Sustainment Systems
POC	Point of Contact
POL	Petroleum, Oil, and Lubricants
RAM/RAM-D	Reliability, Availability and Maintainability (Durability)
SBIR	Small Business Innovation Research
TARDEC	Tank Automotive Research, Development, and Engineering Center
TEMPER	Tent, Extendable, Modular, Personnel
TQG	Tactical Quiet Generator
TRICON	Triple Container (one-third the size of a standard 20’ ISO container)
TRL	Technology Readiness Level
VAC/VDC	Volts Alternating Current; Volts Direct Current
WAC/WDC	Watts Alternating Current; Watts Direct Current

B.1 PowerShade Cost Reduction (PSHADE)

TRL: PowerShade (PSHADE) Gen I variants have been demonstrated both outside the continental US (i.e., Djibouti), and in multiple military locations in the continental US (Hurlburt Field, FL; Port Hueneme, CA; West Point, NY; et al). The PSHADE Gen II variant was demonstrated at Fort Leonard Wood, MO in support of the SLB-STO-D. The TRL is therefore a minimum of 7, with potential for 8 in the Gen I variant.

Standardization, Interoperability: The PSHADE fabric sections are manufactured from commercially available components (fabric mesh used in solar shades, fabric webbing used in tension straps, etc.), and utilize thin film amorphous silicon modules made in the USA, which are available from the manufacturer – PowerFilm, Inc. The support poles are manufactured in the USA using extruded metal and common welding techniques. The ancillary items (stakes, tension straps, etc.) are available commercially. The Multi-Mode Grid Tie Balance of Systems (MMGT-BOS) units are available from the manufacturer – PowerFilm, Inc. – and utilize commercially available electronic components inside. The batteries for use in the MMGT-BOS battery boxes are available commercially and through the national stock number (NSN) supply chain. The system can supply single phase power to a grid.

Tailorability, Modularity, Versatility, Scalability: The fabric sections of the PSHADE are constructed in a modular fashion. Each PSHADE requires a minimum of one lace fabric end section, and one grommet fabric end section. From there, sets of lace and grommet fabric mid-sections are added to increase the energy harvesting capability of the PSHADE. The requisite support poles for the fabric sections are available in "long" and "short" variants, and a minimum of three sets are required. Each addition of a set of lace and grommet fabric mid-sections requires an additional two sets of support poles. All other ancillary support items (stakes, ratchets, etc.) are likewise increased from the base requirement. The latest variant of the BOS is the MMGT-BOS. The MMGT-BOS consists at a minimum of just the MMGT-BOS control box when operating in "Grid-Tie without battery" mode. If energy storage is desired, one or more battery boxes can be added to the MMGT control box to provide that capability. Each battery box holds two NSN# 6140-01-485-1472 batteries (HMMWV lead-acid absorbent glass mat (AGM) batteries).

Net Ready: The PSHADE and associated MMGT-BOS items are not intended to be connected to the internet or other communications infrastructure. This attribute does not apply.

Manpower: The PSHADE fabric sections and associated support poles, stakes, ratchets, etc., are typically erected by a small team of about six personnel, but can be accomplished with as little as four personnel. Tensioning of the fabric structure can then be completed by a smaller team of two to four personnel. Erection and tensioning of the PSHADE structure can be accomplished by an average skilled team in approximately 3 hours, with an experienced team typically taking less than 2 hours. Installation of the MMGT-BOS units can be accomplished by one or two personnel, and typically takes less than 1 hour including the loading of the batteries. User-level maintenance on an installed PSHADE system typically is limited to checking the tension on the straps and ensuring there is no excessive debris (sticks, leaves, snow, etc.) on the fabric sections that would impede light from reaching the photovoltaic panels. This is typically done on an

"every other day" basis, or immediately after a weather event, and typically takes less than 10 minutes with adjustments to the tension straps figured in. If the PSHADE has been installed in an open area, and has been installed for a period of time where the tension in the straps is stable, checking the tension on the straps is typically less than a 5 minute task, and is completed as part of a "walk-around" check.

Personnel Capabilities: The PSHADE and associated MMGT-BOS items can be supported with existing personnel. No specialized MOS is required. Erecting/strike of the PSHADE fabric sections requires no specialized skills, and is typically led by a junior Non-Commissioned Officer (NCO). The MMGT-BOS requires no specialized skills to install or operate, but the camp commander may require someone with electrical experience to ensure the grounding rod and associated cabling are installed, and that installation of the MMGT-BOS inter-unit wiring is supervised.

HFE, Complexity: The PSHADE uses a military standard "becket and lace" system that is commonly used in other shelter items for connecting the fabric sections together. All associated down-drop cables are polarized and/or keyed to ensure correct mating. The PSHADE support poles use captive hardware for pole height adjustment, and the ratchet straps use common "swing gate" protected hooks to attach to the fabric section D-rings for tensioning. The MMGT-BOS connectors and cables are polarized and/or keyed to ensure correct mating, and the battery terminals are color-coded to ensure correct battery terminal selection.

System Safety: The operating voltage of the PSHADE Gen II is ~30 VDC with all of the connectors being fully insulated with no exposed contacts. The Voc (open circuit voltage, i.e., no load) is 44 VDC, defined as SELV (Safety Extra Low Voltage) by the International Electrotechnical Commission (IEC). (IEC 60950 defines hazardous voltage as being above 42.4 VAC or 60 VDC.) The working voltage falls well below SELV definition to help assure there are no hazardous voltages present on the PSHADE. The PSHADE Gen II is a high energy product, producing between 60 and 180 amperes (A) at the power point and close to 75 A to 225 A at short circuit current. This makes the PSHADE Gen II a Hazardous Energy Level system as defined by IEC 60950 – "A stored energy level of 20 joules or more, or an available continuous power level of 240 volt-amps (VA) or more, at a potential of 2 V or more." The PSHADE Gen II has a continuous power level of: 1.8 kVA, 3.6 kVA, and 5.4 kVA at 30 VDC (depending on size).

Health Hazards: The PSHADE and associated MMGT-BOS units present minimal hazards provided the user follows the instructions documented in the manuals, wears appropriate Personal Protective Equipment (safety shoes, work gloves, eye protections, etc.) during the installation and strike phases, uses common sense while erecting the system and when connecting electrical cables to the MMGT-BOS, and does not attempt to over-ride the manufacturer provided safety mechanisms included in the design. A full list of identified hazards and employed mitigation methods can be found in the Safety Assessment Report (SAR) for the system.

Training: The PSHADE Gen II and associated MMGT-BOS units come with manufacturer-provided manuals and essential hand tools (sledge-hammer, tape measures, etc.) which cover all

aspects of the lay-out, erection, tensioning, use, and subsequent strike and packing required. Familiarization of the manual by the lead installer (typically a junior NCO) is highly recommended prior to uncrating the system. If required by the camp commander, training and installation support is available from both the manufacturer and the NSRDEC project officer upon request and funding.

Survivability: The PSHADE system is designed to operate in austere locations, and does not require power from the electrical grid to operate, and is therefore not internally affected by fluctuations and variations in the local power grid. Should single-phase power from the MMGT-BOS be used to support the local power grid, and a fluctuation outside of the allowable electrical parameters be encountered, the MMGT-BOS inverter will automatically disconnect from the grid and attempt reconnection after a period of time. The system is not known to be affected by normal EMI levels typically present in a base camp, but has not been tested under HEMP conditions like those that may be experienced during a nuclear weapon detonation. The PSHADE system materials are not known to be affected by a CBRN event, but the system has not been tested through the requisite decontamination process that would be required after such an event.

Reliability: Improvements in materials and manufacturing processes raised the manufacturer's "in use" rating from 3 years for the PSHADE Gen I, to 10 years for the Gen II system, with the “storage" rating remaining steady at 10 years for both the PSHADE Gen I and Gen II variants.

Availability: PSHADE and MMGT-BOS systems are essentially "ready to go" right out of the crate, and come complete with everything needed for installation, including hand tools. The only items not included and that may need to be sourced locally (typically from the motor pool) are the AGM batteries for the MMGT-BOS battery boxes. The system requires initial setup and should be available once set. In environments with snow, the system may not be suitable for continuous installation.

Maintainability: Maintenance required on the PSHADE fabric sections is limited to keeping the structure tensioned, and the photovoltaic panels clear of excessive debris. Should damage to the fabric sections be sustained during operations, repairs can typically be affected *in-situ* using an Army tent field sewing kit. Damaged ancillary components (stakes, straps, etc.) can be sourced directly from the manufacturer, or via any equivalent stocking commercial source (Grainger, McMaster Carr, etc.). User-level maintenance of the MMGT-BOS units is limited to ensuring the electrical connections are tight and the case is kept closed and clean of excessive debris (dust, dirt, standing water, etc.) Damage to the MMGT-BOS units would require coordination with the manufacturer (PowerFilm, Inc.) to resolve, and that contact information is found in all operator manuals.

Sustainability: The PSHADE requires no logistical support tail to install, operate, or strike. The associated MMGT-BOS systems require two NSN# 6140-01-485-1472 batteries (i.e., HMMWV lead-acid AGM batteries) per battery box, should energy storage be desired. The replacement schedule of those batteries will be dictated by the amount and depth of charge cycling, and by the unit's standard operating procedure (SOP).

Supportability: The PSHADE and MMGT-BOS units require no expendable supplies to operate, as the systems are essentially "ready to go" right out of the crate and come complete with everything needed for installation, including hand tools. The only items not included, which may need to be sourced locally (typically from the unit's motor pool), are the AGM batteries for the MMGT-BOS battery boxes.

Deployability: The PSHADE and MMGT-BOS units currently come packed for shipment in two international shipment-approved wooden crates suitable for land, air, and/or rail transport. Crate #1 measures 96" x 42" x 30", and Crate #2 measures 96" x 42" x 40". Both are easily handled by a 3K forklift, and can be opened with a simple #2 Phillips head screwdriver, or #2 Phillips bit-equipped drill driver.

Transportability: The PSHADE and MMGT-BOS units currently come packed for shipment in two international shipment-approved wooden crates suitable for land, air, and/or rail transport. Crate #1 measures 96" x 42" x 30", and Crate #2 measures 96" x 42" x 40". Both are easily handled by a 3K forklift, and can be opened with a simple #2 Phillips head screwdriver or #2 Phillips bit-equipped drill driver.

Impact of Footprint: The PSHADE Gen II requires a minimum of 42' x 46' of clear, relatively level, area for set-up of the small variant. Successive increases in power generation capability require an additional 24' x 46′ of footprint. For example, the Gen II medium PSHADE variant demonstrated at Fort Leonard Wood, MO required 66' x 46' of footprint. It should be noted that this allowed for a 32' TEMPER air-supported tent to be erected under the Gen II PSHADE with no additional footprint required, making the actual additional footprint required by adding a PSHADE to an existing shelter already on a base camp minimal.

Cost/Affordability: Due to the limited production nature of the PSHADE Gen II and MMGT-BOS units, it is difficult to give an exact dollar figure for replacement value. It is expected that the medium variant of the PSHADE Gen II could be procured in larger quantities at under $40,000 per unit, and the MMGT-BOS unit would be priced at under $12,000 per unit in larger quantities. All pricing would depend upon order quantity and delivery requirements, as well as the ability of the manufacturer (PowerFilm, Inc.) to meet those requirements.

Soldier Feedback *Demo 1, CBITEC, 1000-man camp (Prime Power School)*

Employment of PSHADE – Soldiers' feedback and concerns regarding PSHADE use were captured as follows:

- Used for small power requirements, perhaps tents at pre-deployment locations.
- The advantage of the additional power generated is outweighed by the additional logistical and manpower requirements of the system.
- A unit would carry an additional 5K generator, rather than carry this system.
- Does power generated from this system bring a generator off line? If not, Soldiers are not interested.
- Cost benefit analysis required to determine payoff. System adds equipment for each tent (item being shaded).

- Signal units may like this system (if it's light enough). Could be used in training sites. Footprint of camp not impacted.

Supportability of PSHADE – Soldiers voiced their concerns on various aspects of supportability as follows:

- If one panel goes down, is the whole system off line? (Editor's note: The Technology Provider responds, "The answer is 'No.' The affected panel would not produce power, the rest of the system would continue to function as intended.")
- What is the weight comparison compared to traditional camouflage netting?

Maintainability of PSHADE – Maintainability issues from Soldiers are captured below:

- It's going to get dirty quickly and lose capacity. Needs water to clean, which is scarce in small sites. (Editor's note: The Technology Provider responds, "In actuality, field trials have shown that the vast majority of dust and debris that may land on the PowerShade will be cleaned off by the natural wind induced flutter caused and the remaining minimal amount of dust, pollen, etc., will be removed in large part by the natural washing action of rain. Further, a slight coating of dust actually INCREASES the power produced by reflecting reflected light energy (i.e., photons) back into the PV modules.")
- What is the durability in wind?
- Do you need to lower the system to the ground to perform maintenance on it?
- No known MOS for maintaining this. At Bagram, contractors had to maintain all solar.
- Concerns with durability of tent and strap material.
- Anything above arm's range is not good; something at ground level would be better.

Potential improvements to PSHADE – Soldiers provided recommendations as follows:

- Weight is a key attribute and challenge.
- Can the solar panels be detached from the tent versus being part of the tent? (Editor's note: The Technology Provider responds, "In the Gen I system - No, but the Gen II PV modules are designed to be field-removable and replaceable.")

Lessons Learned *Demo 1, CBITEC, 1000-man camp*

The PSHADE technology successfully produced and stored power for use in the display area.

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B.2 Self-Powered Solar Water Heater (SPSWH)

TRL: Demonstrated in representative environment, TRL 4.

Standardization, Interoperability: Army Small Business Innovation Research (SBIR) enhancement for manufacturability by 2018.

Tailorability, Modularity, Versatility, Scalability: One SPSWH per kitchen; two SPSWH per shower; total of three SPSWH systems for a small camp.

Net Ready: Self-tracking solar; global positioning system optional; network not needed.

Manpower: Installation/setup by four personnel in 4 hours. Daily operation/safety monitoring by one person. Maintenance by one person.

Personnel Capabilities: Support by existing personnel; MOS 92G; special tools included with system.

HFE, Complexity: Leveraged the battery of the Modern Burn Unit (a field kitchen subsystem) to store/use power. Fork-truck required for setup and stowing system.

System Safety: 24 VDC. Connectors are color-coded to cabling. 200-Watt solar panels recharge battery daily.

Health Hazards: Hot water/steam lines; high wind hazard; pinch hazards (track/frame movement); electrocution hazard. Hazard of looking straight into high intensity light source.

Training: Manufacturer-provided manuals. Recommend new equipment training for operators and maintainers.

Survivability: Designed to withstand 70 mph wind. Will self-stow in higher wind. EMI/HEMP yet to be tested, but unlikely.

Reliability: MTBF yet to be evaluated. Typical 30-year life intended.

Availability: Three systems ready-to-go. Pack into single TRICON. Systems would only be operational during periods of daylight. Night, cloudy, and foggy conditions disable the system.

Maintainability: Maintenance tasks include providing a water supply, cleaning the mirror, checking track leveling, torque bolts, clear debris, and corrosion prevention.

Sustainability: Weekly cleaning of mirror, hosing it down in some environments.

Supportability: De-scaler may be needed (monthly).

Deployability: Three systems ready-to-go. Pack into single TRICON.

Transportability: TRICON, 8' x 8' x 6.5'.

Impact of Footprint: Minimum 15'x15' of clear, relatively level area for setup; 25'x25' safety perimeter.

Cost/Affordability: Estimated production cost is $25,000 per SPSWH system, not including the

TRICON container. Containerized system would be three times $25,000 plus $5000 for the container, for a total of $80,000. The system design is being refined under an Army SBIR Phase II Enhancement initiative to improve the performance and reliability, while reducing the complexity and cost of the system.

Soldier Feedback: *Demo 2, BCIL (Infantry Squad, 82d Airborne Division)*

The Soldiers liked that "everything can be picked up by a four-man group," it can be set up in 3-4 hours, it can be easily serviced, "it follows the sun," and it can be stored in a TRICON. They also liked that it "has the capability to generate power" and can function as a generator. The Soldiers would "definitely use this system" and agreed the "capabilities are endless" with the SPSWH because there is "a lot of science behind it, but a lot of common sense too." Although they thought the system would be appropriate for use on a base camp, the Soldiers said that they would only set it up if they were going to be somewhere longer than 3-4 weeks. Another Soldier explained that "it does take up some space" and because the system looks like a satellite, "it's going to be a reference point for mortar attacks." This Soldier also said "I'd rather them hit that [SPSWH] than our TOC." The Soldiers then said one to two systems would heat enough water for a platoon of Soldiers and three systems could generate enough heated water for 150 personnel. They also agreed it would be practical to have one system per kitchen.

Next, the Soldiers were asked if anyone could operate the system. All of the Soldiers agreed that the system is "so simple" because it "detects sunlight and operates itself." Although simple, they said there should still be someone who is trained on the system so they are able to show other Soldiers how to use it. The Soldiers said the engineers "thought of literally everything" and liked that the system resets itself back to facing east at sunset and that the "only maintenance is lubricating it." They were enthusiastic about the change from 4 to 16 mirror panels they were told would be incorporated into the next SPSWH iteration: "Because there are 16 mirrors, single mirrors could be replaced instead of taking the entire panel off. At some point, something is going to break, so you can replace any one and swap them." Their only suggestion for improvement for the mirrors was that the four mirrors in the center could be removed because they "are not getting much sun anyway when it is pointed at the sun."

The Soldiers then discussed logistics of transporting the system. They liked that three SPSWH systems could fit into a TRICON because a Blackhawk [helicopter] would be able to transport them in the TRICON. The Soldiers also commented that that they would "not be surprised to see this system put on a trailer at some point" to make transport and movement even easier.

Lastly, Soldiers discussed potential challenges using the system and durability concerns. The main challenge they could foresee using this system in the field is when it "loses the sun behind clouds" because it requires someone to manually reset the system. The Soldiers were also concerned about the reliability of automatically tracking the sun because they were told by the system's engineer that it was "having some issues with tracking and sometimes it was just a little bit off." Overall, the Soldiers were not concerned about the system's durability because it is waterproof and is a "smart system that sets itself down in high winds [75 mph]." Their only concern was using the system in an area with lots of sand or dirt because they would need pressurized water to clean it off of the mirrors.

Lessons Learned: *Demo 2, BCIL*

Notes from AAR:

- Experienced temperature loss in water hose; couldn't deliver hot water as quickly as desired.
- Input from Soldiers:
  - Great to save fuel, but did not want to operate it; found that it requires some failsafe features – run out of water, drive out of the sun.
  - Integration was a challenge; series of valves to run this experiment; learned that an increase in pressure and flow is needed.
  - Reduce complexity; idea is accepted.
  - Portability and human factors are a concern.
- SEIT after-action notes:
  - The water line (100 feet) that connected the SPSWH to the AWH400 water heater caused cooler water in the line to enter the AWH400 which triggered the AWH400 to start heating the water coming in on the line. This impacted the fuel saving ability of the SPSWH, because it turned on the AWH400 pre-maturely.
  - In a real-world hot water flow, the SPSWH cannot draw thermal energy for its thermal storage device fast enough to maintain the required output temperature of 130 degree F.
  - The SPSWH cannot operate at the 70 psi pressure provided by the fresh water pump which resulted in decreased pressure at the shower head (interoperability issue).

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B.3 HDT 42K BTU Environmental Control Unit (HDT 42K)

TRL: TRL 5

Standardization, Interoperability: One for one replacement with F100 ECU. Same duct size. No change to the plenum, same flow rate. Marketed with V1.5 TEMPER shelter.

Tailorability, Modularity, Versatility, Scalability: Increased versatility to apply to smaller structures and apply to baseline shelter. Variable speed compressor lends to more tailorable in varying climates.

Net Ready: No current "smarts" built in. Engineering change proposal (ECP) could be done similar to F100.

Manpower: System is 250 lb lighter than F100. Easier to shift into exact position.

Personnel Capabilities: Same as F100, remote tethered to ECU, etc.

HFE, Complexity: Less noise. STO-D took noise decibel (dB) measurements at demo.

System Safety: Safety release for demo received. No apparent safety concerns.

Health Hazards: Possibility for improved air quality over the F100, but this has not been tested.

Training: Additional training for repairs but no additional training increase for operation.

Survivability: Same as F100, requires additional testing to verify.

Reliability: TBD. Requires additional durability testing.

Availability: TBD. Requires additional durability testing.

Maintainability: TBD. Requires additional durability testing.

Sustainability: TBD. Expected to be similar to current ECU.

Supportability: TBD. Expected to be similar to current ECU.

Deployability: Easier to move small distances, i.e., a few inches, by hand. Otherwise similar to F100.

Transportability: Similar to F100.

Impact of Footprint: Smaller in size and lighter.

Cost/Affordability: Unknown, but assumed similar to F100.

Soldier Feedback: *Demo 1, BCIL, 300-man camp (542d Quartermaster Company - Force Provider)*

The Soldiers said they liked the [HDT 42K] ECU because it was quiet, drained better than other ECUs, was more portable, self-regulating, and more efficient. They liked that it was quiet because it will not wake a Soldier sleeping next to the ECU intake and because "tactically you want to be quiet." One Soldier said that the ECU was "super quiet" and another Soldier said it was "beyond fantastic." The Soldiers then shared that they liked how the [HDT 42K] ECU drained better than other ECUs: "There were plastic tubes and they would back up and pour into the tent. I like that it's a hole and it just drains right out." They also liked the portability of the ECU and that they were able to move it without needing a forklift. The self-regulation and efficiency of the ECU were also well liked by the Soldiers: "I like that you can set it to 70 and once it hits 70, it'll regulate itself, whereas this one [current ECU] just keeps pumping air out." Due to its self-regulation, the Soldiers liked that it was also more efficient, "which in turn saves battery [in the Microgrid Distribution and Storage Unit, a component of the Energy Efficiency Optimization of COP/PB (combat outpost/patrol base) Shelters (E2)], which in turn keeps the generator off."

Lessons Learned 1: *Demo 1, BCIL, 300-man camp*

The HDT 42K ECU units were demonstrated (a) one with the V1.5 LINER as a component of the E2 system and (b) one with a baseline shelter and non-woven composite insulation LINER. Both HDT 42K ECU units performed well and showed reduced energy requirement to cool the shelters.

Lessons Learned 2: *Demo 2, CBITEC*

The HDT 42K ECU was demonstrated with the V1.5 LINER as a baseline comparison for the Shelter Radiant Heating System demonstration. The HDT 42K ECU performed well and capably heated the shelter during the demonstration.

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B.4 Energy Efficient Expedient Shelters with Non-woven Composite Insulation Liners (LINER)

TRL: TRL 9.

Standardization, Interoperability: NSN assigned. Two versions - TEMPER air-supported and TEMPER frame. The vendor, Camel Mfg., could make any pattern required.

Tailorability, Modularity, Versatility, Scalability: Connector parts allow for scalability. Could be tailored for any tent.

Net Ready: N/A.

Manpower: Requires two to four personnel to install. No change from legacy liner.

Personnel Capabilities: No new MOS required.

HFE, Complexity: No additional requirement.

System Safety: Safety confirmation in place for fielding.

Health Hazards: Minimal, due to less resistance to oils, mildew, etc.

Training: N/A.

Survivability: Less resistant to POL items and mildew than baseline tent with single-ply liner.

Reliability: Some straps have been known to tear out. Similar to tent with single-ply liner. If toggles are lost, makes it very difficult to set up.

Availability: Could depend on environment. May need to remove from shelter to dry in the sun occasionally.

Maintainability: Similar to tent with single-ply liner.

Sustainability: No sustainability requirements.

Supportability: Requires a ladder for installation.

Deployability: Very bulky to pack and ship.

Transportability: Very bulky to pack and ship.

Impact of Footprint: Fits inside the shelter and does not add or subtract to base camp footprint. No impact on camp. Pack out is larger, but still occupies the same slot in TRICON container. Fills dead space.

Cost/Affordability: $7500 per liner.

Soldier Feedback: Soldier Feedback has been positive - "like living in a cloud." (NOTE: The LINER was not specifically addressed by any of the Soldier Focus Groups conducted during SLB-STO-D demonstrations.)

Lessons Learned: The LINER is a permanent feature at the BCIL, and therefore was part of all three demonstrations conducted at that venue. Also, prior to SLB-STO-D demonstration, the EDVT collected focused data on the LINER system in two field data collection events. Those data were provided to Army Materiel Systems Analysis Activity for use in model development and calibration. The LINER was employed at Demo 2, CBITEC, as part of the Minimized Logistics Habitat Unit demonstration. Could use elastic around duct openings. Investigate using zippers instead of Velcro® on openings. Consider using toggles instead of straps.

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B.5 Desert Environment Sustainable Efficient Refrigeration Technology (DESERT)

TRL: The 2nd-generation High Efficiency, Multi-Temperature Refrigerated Container System (HE-MTRCS) prototype demonstrated at CBITEC in April of 2015 had a recommended rating of TRL 5 based on: "The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment." The 3rd-generation HE-MTRCS has a recommended rating of TRL 6, because a "representative prototype system, which is well beyond that of TRL 5" entered testing in a "relevant simulated operational environment" at Aberdeen Test Center (ATC) in the Spring of 2016 and has undergone a great deal of testing to validate performance and function relative to the established MTRCS military requirements in extreme environments. Depending on chamber availability at ATC, testing of the 3rd-generation unit may continue until September 2017 — though there is the possibility of finishing in May if chamber dates open up due to the possibility of other projects needing to cancel specific reserved

dates. Testing of the 3rd-generation units at the contractor's facilities will continue through 2017. This includes a long-duration reliability test.

Standardization, Interoperability: The SunDanzer prototypes require no unique tools. All electrical components, fasteners, and subsystems (namely the refrigeration systems) adhere to common industry standards — even if they are bespoke. Communication ports are standard. The vast majority of parts are COTS. The exceptions are electronics from the developers' proprietary product line, and the firmware required to operate it, as well as the generator motor which was manufactured by the vendor to the application specifications. Operators and maintainers would be trained to use the firmware in the onboard electronics to diagnose issues, but are not expected to maintain the firmware itself. This system isn't any more complex than many other military systems. Container is standard, only change is to the refrigeration system and some of the supply electronics (electrical boxes, etc.).

Tailorability, Modularity, Versatility, Scalability: The intent of improving the refrigeration unit relative to the old MTRCS stock system did not involve modularity or scalability. Those factors were already baked into the MTRCS concept itself. The intent of the DESERT project was to operate at a much greater efficiency to save fuel, operate effectively at the high ambient temperatures encountered in the Middle East, improve reliability, and enable solar capability. The introduction of solar capability improved versatility, because the electronics necessary enable additional electrical inputs, as well as simultaneous operation from different types of power supplies.

Network Ready: The DESERT project goals do not include the development of network capability. Nevertheless, for purposes of improving data visibility during testing, and remote upload of firmware revisions, the vendor installed WiFi and cellular capability for access to some onboard electronics. During field operation, similar communication capabilities with the flexible and capable electronics already aboard the prototypes would enhance interoperability with smart grids, to be used for peak shaving or load leveling, but it is too soon to settle on a configuration. Configuration guidance is on the way, however. The publication of the Tactical Microgrid Standards Consortium (TMSC) regulations for net readiness and interoperability for communications is due in 2018. There is a draft of the document in existence, but not yet available to researchers. Two informative links regarding the TMSC are:

https://community.apan.org/wg/tactical-microgrids/p/howtoparticipate
http://www.slideshare.net/sandiaecis/83tmsc-overviewbozadaeprisnl-microgrid-symposium

Manpower: It is possible for one person to operate this equipment while at the same time they have other duties. The MTRCS is intended to run entirely without intervention; therefore, this person's duties would be to check certain readings or functions periodically to make sure everything is going well. Some issues will be resolvable easily, while others might require more involved mechanical intervention. Same overall manpower requirement as legacy system.

Personnel Capabilities: No additional MOS is necessary. The only one needed is a refrigeration mechanic (91C) in the event there is a problem. The refrigerant is R-134a. A person operating, monitoring, and maintaining the system on an ordinary basis will need no special qualifications.

HFE, Complexity: The control interfaces were designed to promote effective Soldier-to-machine interaction when needed for monitoring or troubleshooting.

System Safety: Safety risks to the equipment are for the most part commonplace and no different in severity, frequency, or probability than similar systems with mitigation plans in place. For example: the operating voltages range from 110-240 VAC; all components meet United Laboratories (UL) and National Electrical Code specifications such as insulated contacts, properly sized wiring and relays, and fuses or circuit breakers; all electrical components, either through their construction or their enclosures, meet National Electrical Manufacturers Association 6 standard for dust and water ingress; and the control firmware includes logic that protects the machine, mechanically and electrically. One deviation from what is commonly thought of as the norm is that some voltages are as high as 350 VDC. This type of electricity, though less common, is considered one of the acceptable standards in electrical components, including motors.

Health Hazards: The risks to humans presented by this system are commonplace and no different than similar systems with mitigation plans in place. For example, there are moving parts (i.e., fans), but guards are in place to bar inquiring appendages. There are standard voltages present throughout the system, but insulation and fuses prevent electrocution.

Training: When trained to established standards, Soldiers representative of the target audience population with the required critical skills, knowledge, and abilities are able to perform all critical tasks safely, with no exposure to uncontrolled health hazards. Training materials can be easily developed, and the level of effort to train personnel for various tasks is not significantly different from similar systems.

Survivability: The HE-MTRCS does not degrade base camp or Soldier survivability, and is hardened for extreme weather and rough transportation. It is identical to the original MTRCS with regard to operation in a CBRN environment, limited to the container paint being Chemical Agent Resistant Coating.

Reliability: The system is expected to be twice as reliable as current systems in use. A trusted engineering rule-of-thumb for engines and pumps is that if they run for half as much time, and/or at lower speeds, they will last twice as long. The refrigeration compressor and fans, and the genset engine, are all variable-speed. Performance testing has proven a 50% reduced duty cycle. Furthermore, variable-speed drives eliminate extreme mechanical forces and electrical inrush. A 3rd-generation HE-MTRCS prototype will enter long-term reliability testing in 2017.

Availability: The system is expected to be always available. It meets all existing requirements of the current MTRCS.

Maintainability: The system is expected to require some, but not excessive, maintenance. Same as legacy system.

Sustainability: The technology is easily sustainable with the resources available to a base camp.

The HE-MTRCS will cut fuel consumption by 30% on an annual basis, and 50% during hot seasons. And because it operates properly in extremely hot environments, perishable food will last longer.

Supportability: Expendable supplies come from routine maintenance of the onboard auxiliary power unit engine. They include oil filters, air filters, and used engine oil. It is not expected they will take up much space as cargo or in storage.

Deployability: Each MTRCS is a single, standard 20' shipping container. Implementation of the HE-MTRCS technologies has slightly lowered the weight of the system as a whole. In addition, the new refrigeration unit has a shallower dimension back-to-front than the unit being replaced. This was done because the Army's HEMTT-Palletized Load System has destroyed many of the older refrigeration units in the field. The dimensions of the new SunDanzer unit will keep it out of harm's way.

Transportability: The installation of a High-Efficiency Refrigeration Unit (HERU) in a stock MTRCS platform does not significantly change the transportability.

Impact of Footprint: The HERU demonstration platform is installed aboard a stock MTRCS container in place of the old refrigeration unit. Thus there is no impact on the original footprint. This technology has no negative impact on the base camp space or logistics, though it could be argued that when a solar array is being used, that will have an impact. However, the solar array is an external system, and if built into tent fabric – as was demonstrated at CBITEC with the HE-MTRCS and at the Ft. Devens BCIL with the OACIS – need not take up any extra camp space.

Cost/Affordability: A spreadsheet was created to determine the affordability of the HE-MTRCS technology. Assuming the return on investment is due entirely to fuel savings, the full procurement cost of each HERU purchased will be completely offset in a period of 18 months. Will look at Fully-Burdened Cost Tool and STO-D simulation results to update this.

Soldier Feedback: Soldiers were not surveyed for feedback on the DESERT.

Lessons Learned: *Demo 1, CBITEC, 1000-man camp*

The DESERT was able to maintain its internal temperature during normal operations and during preparation for the field feeding operation for 800 Soldiers. Data showed only a few very brief spikes in the internal temperature of the refrigerated section during a period of many door openings to prepare rations for the field feeding operation. The DESERT quickly recovered. The freezer compartment required some configuration updates to control icing of the fins and defrosting. On 17 April, it was found that the freezer could not recover the -5 °C setpoint after transferring meals from freezer to refrigerator and putting ice in the freezer. SunDanzer defrosted the freezer and modified the defrost algorithms. The freezer was then able to maintain its setpoint during normal operations on 20 April. The DESERT performed well. As a result of the extensive field demo, SunDanzer identified three areas in which to focus further investigation and/or maturity, (a) low refrigerant pressure switch settings, (b) defrost duration in high humidity conditions, and (c) switch from cooling to heat to maintain set-point temperature. The Lessons

Learned have been folded into the design of the 3rd-generation prototype currently being tested at ATC, during which additional lessons are being learned and reiterated into the design.

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B.6 Modular Appliances for Configurable Kitchens (MACK)

TRL: The MACK could fall under TRL 6 or TRL 7 depending on how definitions are interpreted.

Standardization, Interoperability: Utilizes standard parts and interfaces and won't require special tools. The goal of the MACK program is to develop a modular suite of appliances common across all Army field feeding platforms. Appliances will be standardized from kitchen to kitchen and interoperable.

Tailorability, Modularity, Versatility, Scalability: The MACK appliances are designed to be tailorable, modular, versatile, and scalable.

Net Ready: No network capability or requirement.

Manpower: No change in manpower requirement.

Personnel Capabilities: No additional MOS necessary, operated by team of 92Gs just like legacy kitchens.

HFE, Complexity: Appliance suite designed with simplicity in mind. Common parts used to the greatest extent possible, including a common burner unit that is used in each appliance. It's the Army's intention for it to be utilized as the common burner in all Army field kitchens.

System Safety: System is safe to operate. Appliances were demonstrated at CBITEC with a safety release. No safety risks beyond those typical of an Army kitchen environment.

Health Hazards: New ventilation system will vent combustion gases from kitchen work space and from being in direct contact with food product. In this respect the kitchen should have fewer health hazards than legacy equipment. Internal kitchen temperature is also reduced.

Training: Training materials would not be much unlike currently fielded system. In fact, training will be simpler with MACK appliances because they will be common across all Army kitchens. Currently, each Army kitchen has its own suite of appliances.

Survivability: The MACK appliances do not degrade base camp or Soldier survivability. Commonality of parts between appliances could enable the operator to repair an appliance if it were damaged. For example, if the burner was damaged in one appliance, it could be swapped into another appliance if necessary.

Reliability: The system is very reliable (based on demonstration only). No formal RAM testing done on this system yet.

Availability: This system is expected to always be available.

Maintainability: This system is easy to maintain, and will only require replacement of common parts as they wear. The appliances are modular, so as parts wear and/or break they can easily be swapped out. Depending on the level of damage, some maintenance can be done at the operator level while some would need additional resources.

Sustainability: Fuel must be brought to this technology.

Supportability: Technology is designed to be easily supported. The use of commonly available parts was emphasized early in development process. Fuel is required for this technology.

Deployability: Appliances are locked down to the kitchen floor. Once fuel and power is available, they are ready to operate. Camlock system for securing appliances is an advantage over the legacy systems. Majority of damage in legacy system comes from transportation. Takes less Soldier time for pack-out.

Transportability: No additional unit assets will be required for transportation. The MACK appliances are drop-in replacements for the currently fielded appliances.

Impact of Footprint: No impact; won't change the footprint of any kitchen integrated with appliances.

Cost/Affordability: Fuel-fired appliances will cost more than electrical appliances initially, but the return on investment will be made up in total life-cycle costs over time. A suite of ten appliances will cost about $100,000, independent of the kitchen platform on which they are integrated.

Soldier Feedback: *Demo 1, CBITEC, 1000-man camp (Soldier cooks from various units on Fort Leonard Wood)*

Positive Features:

- Containerized Kitchen – Improved (CK-I) and MACK layouts are superior to legacy CK
- Two ovens (bigger than CK oven)
- Oven racks and fans
- Improved food quality from ovens
- More efficient meal preparation
- Safer work environment (does not get as hot as CK)
- Lighting
- Can cook three items on MACK griddles without cross-contamination
- Griddle height
- Number of serving wells and height of serving line

Suggestions for Improvement:

- Make trailer-mounted
- Decrease kitchen setup time
- Add tray pack heater and small fridge to the MACK
- Add table next to stove/griddles for pans
- Larger grease traps
- Put grease traps on side of griddle and not above controls
- More durable griddle surfaces
- Improve temperature consistency between all griddles
- Add thermometers to griddles
- Longer griddles
- Hotter skillets (i.e. reduce the time needed to bring to temperature)
- Non-stick cooking surface for skillets
- Increase capacity of skillets to 15-20 gallons
- Add separate water spigot for boiling water
- Add "adjustment" to raise skillet off of heat source
- Add vents for steam in skillet covers
- Improve ease of use of skillet covers
- Add thermometers to outside of oven doors
- Slide-out oven racks
- Decrease pre-heat time for ovens
- Bigger opening for serving line drain
- Serving line needs to be leveled or slanted toward the drain
- Improve quality of serving well gaskets
- Add heat guard and sneeze guard to serving line
- More warming cabinet space

Lessons Learned: *Demo 1, CBITEC, 1000-man camp*

Several Lessons Learned, many incorporated into newer generations of appliances. The MACK demo was a great success, both technically and operationally. The field feeding operation was a major training event at Fort Leonard Wood and received much attention from the post leadership and the media. It was evident that the kitchen consumed very little electrical power in the preparation of the meals. Much of the electrical power was for lighting and the on-board refrigerator. The majority of the energy required for cooking was provided by the JP-8 fuel in the appliances. Lessons learned were transitioned to PdM-FSS for incorporation in Battlefield Kitchen.

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B.7 Expeditionary TRICON Kitchen System Appliance Integration (FF-ETK)

TRL: The FF-ETK could fall under TRL 6 or TRL 7 depending on how definitions are interpreted.

Standardization, Interoperability: Utilizes standard parts and interfaces and won't require

special tools. Since the FF-ETK is intended to be a drop-in replacement for electric ETK there would be a difference in training, but it would be relatively minor. In some aspects it may even been simpler.

Tailorability, Modularity, Versatility, Scalability: New appliance suite is tailorable, modular, versatile, and scalable by design. Although different in some minor ways, the interfaces, footprint, and overall design scheme are the same as those utilized by the Battlefield Kitchen. It is the intention of the Combined Arms Support Command and PdM-FSS to move towards a single suite of appliances for all Army kitchens. This would include the FF-ETK.

Net Ready: No network capability.

Manpower: No change in manpower requirement.

Personnel Capabilities: No additional MOS necessary; operated by team of 92Gs just like legacy kitchen.

HFE, Complexity: Appliance suite designed with simplicity in mind. Common parts used to the greatest extent possible, including a common burner unit that is used in each appliance. It's the Army's intention for it to be utilized as the common burner in all Army field kitchens.

System Safety: System is safe to operate, appliances are very similar to those demonstrated as part of the MACK program which received a safety release. No safety risks beyond those typical of an Army kitchen environment.

Health Hazards: No health hazards beyond those typical of the legacy ETK.

Training: Training materials would not be much unlike currently fielded system. In some respects training will be simpler with FF-ETK because it will have the same appliances very similar to other Army kitchens. The ETK currently uses commercial electric appliances. The Force Provider legacy kitchen does not have a program of instruction. As a cross-platform suite of appliances, this will.

Survivability: The FF-ETK does not degrade base camp or Soldier survivability. Commonality of parts between appliances could enable the operator to repair an appliance if it were damaged. For example, if the burner was damaged in one appliance, it could be swapped into another appliance if necessary.

Reliability: Although no formal reliability testing has been carried out on the FF-ETK appliances, the system is thought to be very reliable.

Availability: This system is expected to always be available, similar to other food preparation equipment.

Maintainability: This system is easy to maintain, will only require replacement of common parts as they wear. The appliances are modular, so as parts wear and/or break they can easily be swapped out. Common appliances among kitchens may mean more available replacement parts.

Sustainability: Depending on the level of service, some maintenance can be done at the operator level while some would need additional resources. Maintenance would be performed by 92G.

Supportability: Technology is designed to be easily supported. The use of commonly available parts was emphasized early in development process. Should document what refrigerant is used. Will require fuel source.

Deployability: System is easily deployable with unit equipment. The ETK utilizes a two-wall expandable TRICON container, and, like other Force Provider systems, the FF-ETK is just as easy to set up.

Transportability: No additional unit assets will be required for transportation. The FF-ETK is a drop-in replacement for the currently fielded system and has the same transportation requirements.

Impact of Footprint: Appliance suite integrates into same two-wall expandable TRICON container; no impact on footprint.

Cost/Affordability: Fuel-fired appliances will cost more than electrical appliances initially, but the return on investment will be made up in total life-cycle costs over time.

Soldier Feedback: (Soldiers participating in the Demo 1, BCIL, 300-man camp demonstration, were not trained on the FF-ETK. Hence, this system was not included in the Soldier Focus Group for this demo.)

Lessons Learned: *Demo 1, BCIL, 300-man camp*

There were several Lessons Learned during demo, and many were incorporated into FF-ETK 2.0, which is currently under development. This is another prototype partially funded by Force Provider. Will have an updated set of appliances. Some general observations from the demonstration follow:

- The electrical energy required for operation of the FF-ETK was far less than that of the baseline. The tradeoff is a few gallons of fuel.
- The quantity of water used in preparing meals and sanitizing equipment varied. It is not clear the reason.
- The internal temperatures in the kitchens were monitored to assess QoL for the cooks. Temperatures in the serving line area were less for the FF-ETK while temps in the sanitation area were less for the baseline.
- Food preparation time was an hour less for the FF-ETK. The Technical Provider noted this trend during the demonstration.

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B.8 V1.5 Shelter Liner (V1.5)

TRL: TRL-6. Needs further testing through extended deployments.

Standardization, Interoperability: TBD, but appears to be interoperable with existing TEMPER air-supported shelters. Older shelter designs may need pre-installation of certain affixing hardware, in order to accept liner.

Tailorability, Modularity, Versatility, Scalability: Less so than incumbent Camel Mfg. Inc. insulated liner, as it has several pre-integrated elements that are designed for one shelter size/configuration. Complexing (scaling) has not yet been advertised.

Net Ready: N/A

Manpower: Reduced manpower requirement, as the system is delivered as a pre-installed liner in new air-supported shelters. In addition, users do not need to install lighting system, as it is pre-integrated.

Personnel Capabilities: No new MOS required.

HFE, Complexity: Less so than incumbent Camel Mfg. Inc. insulated liner, as it has several pre-integrated elements that are designed for one shelter size/configuration. No additional lighting or plenum to install.

System Safety: TBD. Intended to exhibit similar capability to incumbent Camel Mfg. Inc. insulated liner.

Health Hazards: TBD. Intended to exhibit similar capability to incumbent Camel Mfg. Inc. insulated liner.

Training: Reduced training requirement, as the system is delivered as a pre-installed liner in new air-supported shelters. In addition, users do not need to install lighting system or plenum, as they are pre-integrated.

Survivability: Selected technology does not degrade base camp or Soldier survivability.

Reliability: TBD. Intended to exhibit similar capability to incumbent Camel Mfg. Inc. insulated liner.

Availability: Similar to Camel Mfg. Certain components such as the lights may have lower availability (non-standard parts integrated).

Maintainability: TBD. Intended to exhibit similar capability to incumbent Camel Mfg. Inc. insulated liner. Non-porous, not as likely to absorb moisture, etc. Not required to air out as often

as incumbent. Plenum mesh may need to be cleared out on a more frequent basis than incumbent.

Sustainability: Increase in base camp sustainability through improved thermal performance (due to radiant barrier), and re-designed plenum system.

Supportability: TBD. Intended to exhibit similar capability to incumbent Camel Mfg. Inc. insulated liner.

Deployability: TBD. Intended to exhibit similar capability to incumbent Camel Mfg. Inc. insulated liner.

Transportability: Needs to be looked at further. (TBD Reduction in bulk due to low-volume lighting system, and integrated plenum. This system also exhibits less "loft" in the insulation material, resulting in lower overall cube.)

Impact of Footprint: TBD. Intended to exhibit similar capability to incumbent Camel Mfg. Inc. insulated liner.

Cost/Affordability: Increase in cost per unit is likely. Return on investment study and calculation yet to be conducted.

Soldier Feedback: Soldiers were not surveyed on their experience.

Lessons Learned:

Demo 1, BCIL, 300-man camp

The V1.5 liner was demonstrated as a component of the Energy Efficiency (E2) Optimization of COP/PB Shelters.

Demo 2, CBITEC

The V1.5 liner was demonstrated in the same shelter with the Shelter Radiant Heater System. This liner is a positive progression from the existing Camel liner system, resulting in greater occupant comfort, reduced logistics and training requirements, and greater energy efficiency. More lessons to be learned.

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B.9 Deployable Metering and Monitoring System (DMMS)

Assessment of the DMMS is pending data submission.

B.10 Structural Insulated Panel Hut (SIP-Hut)

TRL: The SIP-Hut is currently at TRL 6.

Standardization, Interoperability: The SIP-Hut uses unique insulated panels with a custom cam-lock fastening system. The only "standard" features of the shelter are the size, which is roughly the same as a B-Hut, and the use of standard doors.

Tailorability, Modularity, Versatility, Scalability: The SIP-Hut is not modular. Additional shelter space requires additional units be erected.

Net Ready: NA

Manpower: Construction of the SIP-Hut requires a squad of Soldiers. Construction should take 12 hours or less using common hand tools.

Personnel Capabilities: There is no new MOS required to construct or maintain a SIP-Hut.

HFE, Complexity: The SIP-Hut is a simple design. There are some water intrusion issues with the current design that need to be resolved.

System Safety: Care must be taken during construction. Use of ladders and working with heavy objects requires caution and attention to detail.

Health Hazards: Volatile organic compound emissions are a concern. More study is needed.

Training: One individual should be trained in construction of the shelter and can direct the rest of the squad.

Survivability: The well-insulated shelter could provide some level of protection from NBC contaminants.

Reliability: The shelter should be highly reliable.

Availability: The shelter should be continuously available. The design is such that the system could be disassembled, packed up, moved, and reassembled if desired.

Maintainability: The water intrusion issue should be resolved prior to fielding.

Sustainability: The SIP-Hut requires power and a heating/ventilation/cooling system, such as an ECU.

Supportability: There are no supportability requirements associated with the shelter other than normal housecleaning.

Deployability: All SIP-Hut components should fit in one 20' ISO shipping container.

Transportability: The SIP-Hut components weigh about 10,000 lb and can be shipped in a single 20' ISO container.

Impact of Footprint: The installed footprint will be very similar to a B-Hut or a TEMPER Air-Supported shelter.

Cost/Affordability: Researchers at ERDC (Kreiger, 2015) estimate that the initial cost of a SIP-Hut will be $4,400 more than a B-Hut, but that cost will be recovered in overall life-cycle cost of the shelter.

Soldier Feedback: NA. No Soldiers were surveyed on the SIP-Hut during SLB-STO-D demonstrations at CBITEC.

Lessons Learned 1: *Demo 1, 1000-man camp demo*

There were some instrumentation issues during the demo that precluded obtaining good data. However, qualitatively, it was quite evident that the SIP-Huts used far less electricity than B-Huts to heat the shelters.

Lessons Learned 2: *Demo 2, CBITEC*

The SIP-Huts were not challenged during this demonstration. They are so well insulated it took very little energy to maintain comfortable temperatures."

B.11 HMMWV-Towable, Load-Following 100 kW Power Unit (T100)

TRL: The T100 was demonstrated at the 300-man camp demonstration at Ft Devens, MA in support of the SLB-STO-D Demo. TRL is 7.

Standardization, Interoperability: The T100 is a prototype generator set designed and fabricated by Spectrum Research Corporation per a CERDEC SBIR effort in accordance with military specifications and military standard (MIL-STD) requirements to ensure operational, electrical, and mechanical compatibility with all Department of Defense assets in any tactical environment. The T100 is a HMMWV-Towable, Load-Following generator set designed to vary engine speed based on the load being applied, via Load-Following Power Electronics Control System. The T100 uses a COTS engine (VW TDI 165-5 Marine Engine) that operates on diesel fuel. All electrical components such as the permanent magnet alternator, 3-phase inverter systems, etc., were designed and fabricated by Spectrum Research and Fischer Electric.

Tailorability, Modularity, Versatility, Scalability: The T100 system demonstrates the impact of integrating and employing emerging state of the art COTS items integrated with tailored system controls for load following. Results render a reliable, highly power dense system that provides increased fuel efficiency in both peacetime and war time and does not require additional training for 91D MOS. The design positively impacts size, weight and fuel consumption. This design is scalable for 5 kW to 200 kW applications and can provide a fleet of power systems that

offer the Mission Commander greater operational flexibility, higher operational reliability and availability, and reduces logistics footprint.

Net Ready: The T100 was not designed to be net ready. However, the design can be tailored to enable interface with a microgrid application.

Manpower: The T100 is intended to be operated by one to three trained operators. It can be set up and provide power in 15-30 minutes. This includes positioning, grounding, electrical hook up and starting. User level maintenance requires oil change every 200 hours and refueling as needed by one operator. Length of time of operation on a full tank is between 15.2 to 93.8 h (load ranging from 100% [60 kW] to 0 % [0 kW]).

Personnel Capabilities: The T100 can be supported with either existing personnel or 91D MOS. Installation of T100 requires no specialized skills or tools and is typically headed by Squad Leader or base camp coordinator.

HFE, Complexity: The system is designed to allow maximum access to all sides of the genset for maintenance. The control panel is in accordance with MIL STD 1472G. The T100 provides 3-Phase 120/208 VAC (5-wire), 240/416 VAC, 0.8 power factor, 60 Hz to power kitchens, tents, ECUs, laundry, etc. The T100 must be grounded via grounding rod.

System Safety: The operating voltage of the T100 is 120/208 VAC and 240/416 VAC via split lug connector. The T100 has several safety features: Fault Detection module that protects the genset from high inrush currents and destructive overloads (i.e. short circuits), monitors all 3-phase voltages and detects any presence of high DC (direct current) voltages on the output terminals, UL-approved fuses for 600 VAC/DC (interrupts high DC voltages if the insulated-gate bipolar transistors fail) and an in-line output contactor that trips when a fault is detected. When the safety device is activated, the load is removed until the operator corrects the issue. The T100 has a continuous AC (alternating current) power of 80 kW and a peak power of 100 kW.

Health Hazards: The T100 does not present any health hazards if the user follows the Operator’s and Maintenance Manuals. The T100 must be operated outside.

Training: The T100 comes with an Operator's and Maintenance Manual and a Training Manual that provides a detailed explanation of how to start and operate the generator set. As with any new technology, training of MOS 91D would need to be adapted to address the new features, i.e., power electronic controller and energy storage bank. The rest of the system can be taken care of by a 91D with traditional training.

Survivability: The T100 is designed to start, stop, and operate in all environmental conditions. The system is not known to be affected by normal electromagnetic interference levels present in a base camp. It has not been tested under HEMP conditions. The T100 is not known to be affected by a CBRN event, nor has it been tested through the requisite decontamination process that would be required after such an event.

Reliability: If the operator follows the Operator's and Maintenance Manual for oil changes and system maintenance, the generator set could last as long as the fielded TQG and AMMPS generator sets. It is designed to meet the MTBF requirement of 800 hours.

Availability: The T100 is a prototype system resulting from a CERDEC SBIR. It is not in production. From an operational perspective, the unit will provide full continuous power within 30 minutes of arrival at a given site.

Maintainability: The T100 can be operated for a long period of time through proper maintenance as described in the Operator's and Maintenance Manual. Per the instructions found in the manuals, oil should be changed every 200 hours with regular operation or once a year during peacetime. The operator can easily drain the oil because this engine has the capability to pump the oil out through a coiled rubber hose that is attached to the oil pump. The operator can easily drain the radiator fluid via valves. All the components are accessible via removable panels.

Sustainability: The T100 Operator's and Maintenance Manual provides all the necessary fluid and filter part numbers and websites to purchase these items.

Supportability: The T100 requires Ravenoil WIV 0W30 oil, Hengst E32H-D21 Oil Filters, 50/50 mix of Pentosin Pentofrost E G12 Plus coolant and distilled water, and air filters. The three power electronic boxes use a K&N® washable/reusable filter element that can be washed using a mild detergent, dried and lubricated using a K&N® air filter oil (aerosol can). The T100 Operator's and Maintenance Manual provides all the necessary fluid and filter part numbers.

Deployability: The T100 can be towed by a HMMWV and transported via air and/or rail.

Transportability: The T100 can be towed by a HMMWV and transported via air and/or rail.

Impact of Footprint: The T100 requires a minimum of 13.92′ (L) x 7.12′ (W) x 7.79′ (H), or 772.07 ft^3 of clear, relatively level area for setup. This item can be placed anywhere within the base camp that requires AC power, e.g., kitchens, camp lights, laundry, tents, ECUs, etc. Because the unit can be towed by a HMMWV or other tactical vehicle, power is made available within 30 minutes of arrival and emplacement. (The Capability Needs Analysis requires availability within 2 hours of arrival at a given site.)

Cost/Affordability: Since this is a prototype, the cost of the T100 could range from $240,000 (quantity of 1) to $200,000/set (quantity of 3–5) depending on the delivery requirements.

Soldier Feedback: *Demo 2, BCIL (Infantry Squad, 82d Airborne Division)*

All of the Soldiers said they “love this generator” and that the T100 would be practical in a field environment. One Soldier said “if deploying, it needs a steel frame. It will increase the weight but it needs to be ruggedized.” Another Soldier then said the T100’s hitch should be removable or the system should be slightly smaller so that it can be put inside of a TRICON to be airdropped or it should be made sling-loadable. Some of the Soldiers said a trailer is the “best setup” because it’s “very mobile.” They said there was no minimum time they would need to be

on a base camp, “Whether we’re in the field for one day or 12 hours, if we need electricity, we need this.”

The Soldiers said it could be operated by any Soldier because “it’s plug and play” and the “next generation will be even easier because you will just press a button.” The Soldiers also said any Infantry Soldier could perform basic maintenance of the system because “Infantry companies get 5kW and 10kW [generators] and we are required to know basic functions, so this will just fall on the same lines.” They said access to the inside of the system was easy because “you can take both sides and the top off” and requested that this type of access not be changed. The Soldiers did not think much training would be required to run the system: “just training when it gets assigned to the unit.” The Soldiers were impressed with the system’s ease of use: “It pumped its own oil out – that’s amazing. It practically runs itself”; “This is another common sense product – they thought of everything.”

They envisioned the system being used to power “operations centers and housing” or “to establish a combat outpost away from a major forward operating base (FOB).” All of the Soldiers also said the system could be used to run a platoon-sized FOB with its 100kW because it is “very efficient and very powerful” and does not require “retrofitting” of a vehicle. The Soldiers liked that the T100 “can adjust its load based on what we’re using on the base camp” and also liked the variable speeds because it saves fuel. They viewed the variable speeds as “a big plus.” The Soldiers then explained that having 240/416 V is “good because Europe uses that and it’s good to have for heavy equipment” and said “having the capability [240/416 V] is a must.”

For durability of the system, the Soldiers were concerned about the aluminum on the top of the system “getting worn down quickly” or “bent up,” especially if being sling-loaded. One Soldier said “it would be a one-time fly thing because of the damage it would cause. You would probably risk damaging the inside and the casing would be unserviceable. If you start bending it, it’s not going to come off like it’s intended to. You can’t just bend it back because it snaps.” To mitigate damage done to the system, the Soldiers said they would put tape on friction points and suggested replacing the aluminum with steel.

Lastly, the Soldiers provided suggestions for improvement to the T100 system. The pins on the system’s doors should be anchored so they don’t fall off, making it more durable for sling-loading. Add the ability to siphon gas out of a fuel blivet.

Lessons Learned: *Demo 2, BCIL*

Lesson #1: Operational environments can be very different from those found in a laboratory. As one example, in preparation for meeting the SLB-STO-D entrance requirements, the T100 was tested at both the contractor’s facility and at Aberdeen Proving Grounds using commercial load banks. The T100 provided stable performance during these prequalification tests, yet while operating under the realistic loads found in the BCIL east camp, a small-signal engine speed instability was observed. This was undoubtedly caused by some combination of small-signal load fluctuations, single phase unbalanced loads, rapid load cycling (thermostats), and high inrush currents. Fortunately, the issue was quickly resolved through a firmware modification. For

future development efforts, Spectrum Research Corporation plans to upgrade its in-house testing capabilities to better replicate realistic loads in a controlled laboratory setting.

Lesson #2: Military power source must be designed and tested to the point of failure so that it is known where those limits exist. During the second day of pilot record runs, one of the T100 inverter legs was loaded far in excess of the 100 kW system rating. As a result, one of the inverter modules sustained arc damage which in all likelihood precipitated from a radio frequency corona discharge. Possible root causes include parasitic inductive voltage spikes on the DC bus, or external arcing on the load side, perhaps caused by a loose power connection.

Lesson #3: While the T100 will be upgraded to guard against these and other possible root causes, the T100 subsystems must be packaged into an even more modular format such that they can be quickly repaired in the field.

Comments/Observations: CERDEC Power Division believes that they successfully demonstrated the load following capability of the T100 and its ability to handle 3-phase and single phase loads. Even though one of the six inverters failed, the contractor was able to repair the generator set at his facility in a professional and timely manner. The contractor was dedicated and worked hard 14-16 hours per day to repair the generator set and deliver the system two days before the Army Leadership Day. The T100 was set up and provided power to the East Camp in 30 minutes because of its mobility and ease of use. The T100 provided power to the East Camp (single and 3-phase loads) from 16 May to 8 June and 13–17 June. Overall, the STO-D experience provided valuable insights into transitioning the T100 to the battlefield.

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B.12 Single Common Powertrain Lubrication (SCPL)

TRL: The SCPL has undergone field testing at Ft. Benning, GA, Ft. Bliss, TX, and Ft. Wainwright, AK in more than 40 military vehicles. The SCPL has completed a 20,000 mile RAM-D test at Aberdeen Proving Grounds. The SCPL was demonstrated by CERDEC in TQG and AMMPS generator sets in support of the SLB-STO-D. TRL is 9 for vehicles and generators. There is a certification report.

Standardization, Interoperability: SCPL is manufactured using commercially available components. One benefit of SCPL is that it can operate in many vehicle components including engines, transmissions, and hydraulic systems designed to use engine oils. SCPL is also able to be used in many applications from arctic to desert conditions. So seasonal oil changes would no longer be required.

Tailorability, Modularity, Versatility, Scalability: SCPL can be used in a variety of military equipment and components designed to use engine oil meeting MIL-PRF-2104 for lubrication (engines, transmissions, hydraulic systems, etc.). SCPL was designed to be all-season fluid so it can be used from the arctic to the desert without requiring an oil change.

Net Ready: This attribute does not apply.

Manpower: SCPL is applied like any other engine oil. SCPL does provide extended oil change intervals (e.g., for engines from 6000 miles or 1 year to 12,000 miles or 2 years) compared to standard military lubricants like 15W-40. This reduction in maintenance allows manpower to be spent doing other important work.

Personnel Capabilities: SCPL is applied like any other engine oil so it does not require new or additional skills.

HFE, Complexity: Since SCPL is applied like any other engine oil, this attribute does not apply.

System Safety: SCPL is formulated with common components used in existing military and commercial engine oils. It has similar flammability and toxicity to existing products.

Health Hazards: SCPL is formulated with common components used in existing military and commercial engine oils. It has similar flammability and toxicity as existing products.

Training: SCPL requires no additional training or skills to apply or use beyond what is currently required by existing lubricating oils.

Survivability: SCPL was designed to provide at least a 2% improvement in fuel economy when used to replace 15W-40 in the engine and transmission. For example, during a 20,000 mile RAM-D test using Stryker vehicles, SCPL allowed the vehicle to travel 66 further miles using 27 gallons less of fuel. Such fuel reductions result in less fuel demand and a reduction in fuel convoys which reduces Soldiers' risk.

Reliability: SCPL was designed to maintain similar or better wear control compared to standard military 15W-40 in many components. SCPL's high thermal stability ensures that it can withstand higher temperatures than standard military 15W-40 without breaking down or oxidizing. These attributes should contribute to equivalent or better reliability in many components.

Availability: SCPL potentially improves equipment availability by reducing the need to change oils when a vehicle is transported from an arctic region to a moderate or hot region. In addition, because SCPL allows the doubling of oil change intervals (compared to standard 15W-40), SCPL requires less maintenance so vehicles are more available.

Maintainability: SCPL is an engine oil with standard engine oil shelf life so it takes no additional maintenance than standard 15W-40. In addition, as noted, because SCPL doesn't require seasonal oil changes and doubles oil change intervals, its use leads to reduced maintenance of host vehicles/systems.

Sustainability: SCPL contributes to base camp sustainability by reducing the fuel usage and maintenance of diesel generators and vehicles.

Supportability: As a packaged petroleum product SCPL is ready to use straight from the can and requires no additional tools or equipment that is not already available.

Deployability: SCPL is available in several size containers and the NSNs have been established. Potential to improve unit deployability by eliminating other grades of POL.

Transportability: SCPL allows for the doubling of oil change intervals compared to standard military 15W-40 and thus overall quantities of oil should be reduced.

Impact of Footprint: No additional footprint is required. Footprint related to petroleum products may be reduced because of SCPL's reduction in fuel usage and longer oil change intervals.

Cost/Affordability: Although the cost of the SCPL is currently about 2½ times the cost of standard 15W-40, the difference is mostly offset by the ability to double oil change intervals. Additional cost benefits come from fuel savings which can range from 1-4% depending on the equipment and duty cycle.

Soldier Feedback: Soldiers were not exposed to SCPL during the SLB-STO-D.

Lessons Learned: *CERDEC Fuel Consumption Test*

As part of the fuel consumption test, CERDEC also conducted an Oil Particle Count test on the SCPL and Army 15W-40 diesel engine oil.

Advantages of TARDEC SCPL Synthetic Engine Oil:

- TQG-MEP-805B: SCPL oil performs consistent with the current Army 15W-40 diesel engine oil throughout the 500-hour test, maintaining a slightly lower particle count.
- AMMPS-MEP-1060: The particle count on SCPL was slightly lower than 15W-40 oil between 125 to 350 engine running hours of the 500-hour test.

Disadvantages of TARDEC SCPL Synthetic Engine Oil:

- TQG-MEP-805B: Particle count was higher on synthetic oil at the end of the 70-hour engine break-in period, compared to the 15W-40, but improved after changing oil and filter and taking another sample at 50 hours and throughout the official 500-hour test. This indicates that the recommended 15W-40 manufacturer (John Deere) engine oil performs better on engine break-in.
- AMMPS- MEP-1060: Particle count was higher on synthetic oil at the end of the 70-hour engine break-in period, compared to the 15W-40, but improved after changing oil and filter and taking another sample at 50 hours and throughout the official 500-hour test. This indicates that the recommended 15W-40 manufacturer (Cummins) engine oil performs better on engine break-in. Particle count was higher on SCPL than 15W-40 between 50 to 125 engine running hours. SCPL oil has a higher particle count trend that steadily inclines starting at 350 engine hours throughout the rest of the 500-hour test.

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B.13 Energy Informed Operations-Central (EIO-C)

TRL: The EIO-C is currently at TRL 5 and scheduled to transition at TRL 6 to support the PM E2S2's Management and Distribution Control program in FY18/19. EIO is beyond the fidelity of "breadboard technology" and has been tested in multiple simulated operational environments such as BCIL events, Network Integration Experiments, and Network Modernization events. While some components, e.g., hardware, may have a higher TRL, the controls, software, and a few other features are TRL 6, resulting in the overall system's rating.

Standardization, Interoperability: EIO-C uses both standard and non-standard hardware. The TQGs used are standard military TQGs but with modified controls. Smart, modified TQGs are required as part of this EIO-C microgrid release. These controls enable a standard TQG to communicate with the EIO microgrid. The Intelligent Power Distribution (IPD) boxes are modeled after the existing PDISE boxes. They have been modified to interact with the EIO application and have intelligence to communicate with the EIO app and new control boxes. These IPDs can also have their intelligence turned off, which effectively makes them a standard PDISE. The IPDs connect to power sources and loads using military standard L-Class 100/200 amp cables.

Tailorability, Modularity, Versatility, Scalability: The EIO-C microgrid can be arranged in multiple configurations ranging from 60 kW (two 30 kW TQGs) to 240 kW (four 60 kW TQGs). The grid can be mixed and matched using both 30 and 60 kW TQGs so it can be optimally configured to support the mission's load requirements. Since the EIO-C microgrid has intelligent power management it is not necessary to modify a particular configuration to a load requirement, meaning a larger grid can be configured for a smaller requirement and the grid will adapt. The grid has a generic design of TQGs and IPDs lined up in close proximity with their distribution cables reaching out to the loads. Loads do not have to be directly next to the grid, but long distances can cause voltage drops (300 foot maximum distance from source to load).

Net Ready: The current release of the EIO-C microgrid is not net ready. Design decisions, software selection, and implementation plans, however, set a path for eventual Risk Management Framework accreditation.

Manpower: Any Soldier or civilian can be trained to operate the EIO-C microgrid. It is preferred that Soldiers with mechanical or generator repair expertise, such as a 91-D, be trained to use the system since it may require some maintenance and repairs that they will be able to fix. General TQG maintenance will be required and is dependent on the runtime hours of the TQGs (oil changes, re-fueling, and coolant). No maintenance should need to be performed on the cables or the IPDs. Maintenance can be performed by one individual, but having more personnel will make the maintenance downtime less. The system features a computer with the EIO application that should be monitored for best efficiency. This will require the attention of whomever is in charge of the camp's power systems. For setup, once the pallet is delivered, each IPD is a four-person lift and has handles on the box for easy positioning. Once the TQGs and IPDs are positioned the cables can be moved by one to two personnel depending on the size and length, and then connected.

Personnel Capabilities: No new MOS is required. The EIO app can be taught to current Soldiers supporting power generation. Personnel with training in TQG maintenance are needed to maintain and support the system during peacetime and war. Maintenance will be required on the TQGs and requires knowledge on how to perform each task. These tasks can be taught to others but they do require outside training prior to EIO-C being used in the field. Since EIO-C uses standard military TQGs this training is readily available and can already be known by users and requires no new additional procedures.

HFE, Complexity: EIO-C microgrid does not add complexity compared to similar systems, such as the AMMPS microgrid. The hardware consists of systems already fielded that are slightly modified with improved controls and monitoring. The main feature EIO-C adds to complexity is the EIO application. This application allows the user to tap into the microgrid with a laptop and view what is currently happening, as well as collect and analyze data, alarms, and basic diagnostics. The application requires some training, but the current application training can be done in a single session in the field or previous to live events; both have been done in the past. EIO also has custom, house-made cabling for specific configurations, e.g., female-to-female 200-amp cabling for ring bus connections, which are not readily available in the field.

System Safety: The IPD contains three medium risks, which are as follows: (1) Water ingress into IPD cable connection or connectors during cable connection or disassembly could pose an electrical hazard to both personnel and the IPD equipment. Personnel could be shocked and IPD equipment could short circuit. The system has been designed to reduce the probability of this occurring to remote. (2) Frayed or damaged cables could pose an electrical hazard to personnel and the IPD. Personnel could be shocked and the IPD could short circuit. The User's Manual recommends and the training syllabus reinforces the need to check the cables regularly for damage. Keep the area around the cables clear of clutter and sharp objects. If the cables are damaged, shut down the system and then disconnect and replace them. Do not use the IPD if cables are damaged. Driving over the cabling with vehicles of any kind is not recommended. These efforts, and the use of only approved military standard cables, have reduced the probability to improbable. (3) The current IPD design has double male ring bus ports, which could pose a shock hazard. This is mitigated by proper training and posted signs that indicate a shock hazard. Probability is REMOTE.

Health Hazards: Unrestricted personnel access to the camp's microgrid area (containing EIO TQGs, IPDs, and related power cabling and communication cabling) could unknowingly expose personnel to high voltages. The EIO microgrid equipment and area must be posted with high voltage warning signs. EIO components must be grounded properly. The TQGs must be positioned so the engine exhaust does not infiltrate occupied shelters, tents, buildings, or other structures. Gloves and steel-toed boots must be worn when working with the IPD, even if it is not in use. The gloves and boots will increase personnel protection from possible thermal, electrical, or mechanical injuries.

Training: Users are to be trained on how to correctly connect and disconnect the microgrid as well as making sure it functions properly. This training also covers safety, general operations, and what to expect during system runtime. There will be separate training for users of the EIO application.

Survivability: EIO-C does not degrade base camp or Soldier survivability. If there is a failure, EIO attempts to fail gracefully and keep priority loads powered per operator intent.

Reliability: EIO-C reliability depends on the hourly usage on the TQGs and wear and tear on the IPD connectors and cables. EIO-C improves reliability by optimizing power sources in order to prevent wet-stacking and reduce fuel consumption. If proper maintenance is performed on the TQGs and safety inspections performed regularly on the system connectors and cables, the system should be highly reliable. The system can also run without the application.

Availability: EIO-C is readily available at the start of any mission. The main caveat here is that the system is already set up in place and all cables are connected to their respective loads. If setup is properly performed the micro grid is ready to provide power immediately once all TQGs have booted up. If the mission begins at a random time and EIO-C is not in place, the availability time will depend on the ability for the unit to place all TQGs, IPDs, and connect cabling to loads.

Maintainability: EIO-C maintainability depends on the hours of use on each TQG. General maintenance has to be performed on these depending on run-time hours. The TQG manuals can be referenced for this information. The cables and IPDs should not have to be maintained as long as there is no visible damage to the cables or the IPD itself. If for some reason there is a problem with communications this could be due to a problem in the software. This would require a subject matter expert (SME) to repair. Internal and communication problems are generally identified and resolved before the microgrid is sent an operational event.

Sustainability: EIO-C improves sustainability by reducing the fuel burden on base camps. It also uses preexisting technologies with mostly internal modifications so additional experts are not necessarily needed for operations and general maintenance. EIO-C does bring some new components, needed for intelligent operations, into the logistics trail. This burden is outweighed by the projected overall reduction in maintenance need on each microgrid component.

Supportability: Since EIO-C uses already deployed TQGs there are no special supplies, tools, etc., needed for hardware supportability. Operators should perform general maintenance checks if the components are not be used for a length of time, i.e., make sure fluids are topped off, start up TQGs every so often, look for visible wear and tear when not in use, etc. Software may have updates during downtime in which an SME must have access to the IPDs and TQGs in order to upload and make sure all components are working correctly. This can also be done in the field but will take components of the microgrid offline until the process is complete.

Deployability: There are currently no deployability restraints for EIO-C. Hardware modifications do not have any effect on transport since they are in controls only. Since EIO-C uses standard TQGs, proper handling equipment must be used, such as forklifts and tow trucks, to position them. Some of the EIO-C TQGs are HMMWV-towable and do not require a forklift for positioning. When cables are being delivered for the first time they come in a crate or on a pallet which will also require a forklift for positioning. The IPDs are shipped on pallets and will need a truck/lift for delivery. In the future, when additional components are added, such as inverters and batteries, there may be deployability constraints or obstacles.

Transportability: The TQGs for EIO-C will require trucks and forklifts for transportability. IPDs and cabling may also require the same depending on distance. Cabling and IPDs can also be placed on pallets and moved using a pallet jack or placed in a trailer and towed to the site where EIO is being operated. TQGs will also need a forklift to place the systems where they will be operated and if they ever need to be swapped for replacement or maintenance.

Impact of Footprint: The size of the EIO-C microgrid depends on the configuration. It is ideal to have the loads nearby to eliminate possible voltage drops over the distribution cables, but is not 100% necessary (300 foot max distance between source and the load). Line voltage can be monitored using meters to ensure that quality power is being distributed during the setup phase. Knowing the size and configuration of the grid is important prior to setup so proper space requirements can be allocated. Once the grid is set up there are no extra storage requirements for spare parts. All EIO-C cables and hardware components are made to be outside so they can be placed off site or nearby depending on what is more feasible.

Cost/Affordability: EIO-C is a prototype system. Overall TQG costs will have an increase due to modifications and intelligence placed on them. IPDs are continuously being improved for better reliability and affordability. While hardware costs are initially variable, the overall savings the system provides in maintenance, fuel costs, and other base camp logistics makes up for the initial costs during the system's life cycle.

Soldier Feedback 1: *Demo 1, CBITEC, 1000-man camp (Prime Power School)*

The Soldiers made the following observations regarding the employment of EIO-C:

- Likely best for a light infantry unit with 400-500 Soldiers.
- Discussion regarding the maximum amperage of the system and how the 200-Amp limitation of each IPD would be managed within the grid.
- If the grid eliminates/reduces the need for spot generation, how does this impact the unit's Modified Table of Organization and Equipment (MTOE) (e.g., do they lose dedicated generators currently on their MTOE)?
- Limitation on distance between loads (voltage drops).
- Could be used during retrograde operations (e.g., when power plant is being dismantled).

Comments regarding supportability are captured as follows:

- Generator mechanic could assist in basic maintenance but any detailed repairs would either require additional training for the Soldiers, or dedicated contractor technicians.
- Detailed, well-documented training and instructions could allow some maintenance to be performed by the unit end users.

Soldiers provided feedback on maintainability issues as follows:

- Control (locking) of the system to avoid another unit inadvertently changing the settings and effecting power supplied.
- What would the requirement be for 200 A cables (size, weight, length would be extensive)?

Soldiers provided input on potential improvements as captured below:

- Safety protocols and fail-safe procedures must be implemented to avoid possible over-current on the boxes, if system communications fail.
- The loads should drive the generator operations coming on/off line. Additional load should be commensurate with the size of the generator coming on line.
- Combine HPT and EIO-C systems. Excess power could supply HPT batteries.
- Are all the paralleling challenges being addressed (i.e., phase, frequency, voltage)?

Lessons Learned 1: *Demo 1, CBITEC, 1000-man camp*

The EIO-C successfully powered the grid for the duration of the occupation by the Military Police Officers Course class in the A-block B-Huts. This required 24/7 monitoring of the power systems and CERDEC provided that service. Prior to the operational demo with the Soldiers, there was an opportunity to run scripts to demonstrate the functionality of the EIO-C grid.

Soldier Feedback 2: *Demo 1, BCIL, 300-man camp (542d Quartermaster Company – Force Provider)*

Overall, the Soldiers "loved" the EIO system and described it as the "favorite thing" they saw during the demonstration. They thought that it was a "necessity" and will become "a standard for the military because you can run everything off this system." They shared all of the positives of the system and explained that although they had some suggestions for improvement, the suggestions "weren't to fix anything, they're just how to make it even better" and "more convenient." The Soldiers' top three EIO system likes were the remote capability, load balancing (smart technology), and the ability to adjust ECU temperatures from cell phones. [Editor’s note: This last feature was not demonstrated, but must have been postulated to the Soldiers.]

Regarding the remote capabilities, the Soldiers said they "loved the app" because it provided them with information about the generators and faults. They liked that they could monitor and run all of the generators from their phones and that the fault alert would notify them about what is wrong and what it looks like. They said that it "went above and beyond what we expected to see." For load balancing of generators, the Soldiers liked the "smart technology" of the EIO system since it would run only enough generators for the required load. Lastly, they liked that they would be able to remotely control ECU temperatures from their cell phones. Overall, the Soldiers thought the remote capabilities of the EIO system allowed them to work more efficiently and effectively.

Some of their recommendations included adding a Technical Manual and wiring diagram to the app, adding push notifications and maintenance tasks to the app, adding a dehumidifier to the electronics, adding corrosion protection to the breaker enclosure and handles, and adding automatic switches from "normal to emergency." For system maintenance, the Soldiers thought it would be beneficial to add scheduled maintenance tasks to the app that could be changed based on operational needs. The tasks could have check-in reports that would have to be completed by an assigned end user. They also thought that it would be beneficial to be able to share system

problems with technicians or generator mechanics by uploading pictures of the problems. The Soldiers thought that the IPD enclosure needed a dehumidifier for safety reasons because it can get "moist, and condensation with a big circuit board is the cause of electrical fire. Electronics in there get really hot." The Soldiers also thought that the breaker enclosures and handles should be durable enough for the outdoors to prevent corrosion. Another suggestion made by one Soldier was to add a bypass isolation switch which, from his experience, is very important: "There's a bypass isolation switch. There's a normal power source and there are emergency generators. The bypass switch takes emergency power and transfers. It's used in data centers and hospitals that can't go down at all. It's helpful because you can bypass it and keep it running, so the actual load is still applied to the generator instead of having a break in the line. It automatically switches from normal to emergency."

Lastly, the Soldiers expressed their concern about how "electronics can be hacked." Due to this possibility, they thought that the system needed a manual override because "if something is analog, there's no computerization and it can't be hacked."

Lessons Learned 2: *Demo 1, BCIL, 300-man camp*

The CERDEC team sponsoring the EIO-C took advantage of the opportunity to establish and operate the microgrid in an operationally relevant environment. The team learned a number of lessons during integration, pilot runs, and eventually record runs. Of note:

- Upon arrival there were some code fixes required for the IPDs. The team was able to test and verify the IPD functionality.
- Tested and tuned the load shedding feature and modified the grid layout to accommodate temporary failures.
- Solved issues related to synchronizing multiple generators to the grid. Used load banks and shelters to test the grid.
- Made hardware repairs to the IPDs. Replaced faulty IPD as required.
- Tuned and verified the TQGs. Applied load by steps to verify algorithms.
- Experienced a situation where an IPD "froze." Executed a live workaround to route comms through another IPD making it the master, with no grid blackout.
- Successfully executed four record runs, 21-24 July, with only one crash. The main IPD program went down and generator "reverse power" occurred before it could respond. Two application computers were connected to the same grid. This was an unexpected mode. Recovered the grid and resumed operations within 10 minutes.

Soldier Feedback 3: *Demo 2, BCIL (542d Quartermaster Company - Force Provider)*

The Soldiers were first asked at what size camp this technology would be best suited, how long they would need to be on a base camp to use the EIO, and what they would power with the system. All of the Soldiers agreed the system could be used on a base camp with at least 150 personnel. They also agreed that the EIO would be best suited for a base camp that would be established for at least 6 months and said they would want to start setting up the EIO on day one because "you'd want to be setting it up with everything else." The Soldiers said the EIO would not be suitable for short-term use because a "regular genset could do the same" and it would not

be worth the time required to set up and run Ethernet cables. When asked what they would power with the system, most of the Soldiers said they would power the entire camp. However, one Soldier said he would not power dryers with this system because they would be run off of shore power. [Editor's note: All SLB-STO-D Integrated Solution Sets assume no shore power is available.]

The Soldiers were asked if anyone could operate the system and what training or certification would be required. All of the Soldiers said anyone could run the system once it's set up, but thought it might be set up more quickly by a Soldier whose MOS provides them with more power system experience. In addition, an experienced Soldier would likely benefit more from the system's analytics. But because the EIO is a "very simple system," they said anyone could be cross-trained to understand the analytics. They also agreed that any Soldier could perform "generic maintenance on the generators" because "out in the field, you wouldn't do much more than that anyway." If the Soldiers would be in the field long-term, however, one Soldier said the situation would be different because the EIO would require annual service (oil change, filter changes, etc.). Another Soldier said any Soldier could change filters and they would still not need a specific MOS for this. For training, the Soldiers thought only 1-2 days of training would be necessary for this system because "training on the generator side is simple, but the program to run it requires more in-depth training." The Soldiers then explained that the program training would need to be hands-on, as opposed to a classroom.

The Soldiers then discussed the EIO's graphic user interface (GUI) and reports. All of the Soldiers said the GUI was simple, easy to read, and intuitive. They liked the application and said it would be best used on a tablet or laptop versus a phone because it is easier to use with a larger screen. The Soldiers said this application would be especially helpful in a configuration with a lot of generators that are spread out because it allows a Soldier to track everything connected to the EIO. When asked if the GUI provided enough information, all of the Soldiers agreed that it does: "Yes, you can find everything you needed to find. They did a great job. Whatever information they could pull up, you can get." The Soldiers said the most useful reports from the EIO in the field would be power levels and fuel savings. The engineers then asked the Soldiers about the planning wizard. Most of the Soldiers agreed that it would be helpful because "it tells you what to do, which saves time" and makes camp setup easier.

Next, the Soldiers were asked about the benefits of a smart generator system. The Soldiers liked the idea of a smart generator system because it makes troubleshooting easier, it's easier to monitor, and makes the camp more efficient. One Soldier said "the way this system is set up, the batteries will save on fuel consumption and having to run it out there every day. I feel like it's more efficient with the battery. The way they distribute automatically when things start to kick on, it'll even out the load. It'll save the generators and figuring out the math of what's going to pull from there." Another Soldier said "I think it's nice because you can see the fuel level for anything. If you see it is running low, you can see which ones you have to worry about."

The only safety concern the Soldiers had with the EIO system was tripping on cables, especially on Ethernet cables. The Soldiers said tripping hazards are inherent to any generator system, but because Ethernet cables are more brittle, they were concerned that tripping on one would break

it. They explained, however, that if Soldiers were on a base camp long-term, the cables would be buried, so tripping hazards would not be a concern.

The Soldiers' main suggestions for improvement included incorporating alternative energy sources (e.g., solar, wind), sending automatic notifications, and making the system wireless. The Soldiers said it could help reduce fuel consumption if an alternative energy source was used to charge the EIO batteries, but it would be important to always have the generators as a backup. For the automatic notifications, the Soldiers said it would be "genius" if it "automatically sends notifications to fuel guys" because the notification would alert them that fuel in a particular generator is running low so they are prompted to go fill it.

Lessons Learned 3: *Demo 2, BCIL*

From Technology Provider: Topic - Integration of battery-inverter into Energy Informed Operation (EIO)

Description: For the first time, an energy storage system was integrated into the EIO microgrid. The energy storage system consisted of a bank of sealed lead acid batteries tied in via an inverter producing 208 V, 3-phase power that fed directly into the microgrid bus.

The integration of the energy storage proved to be very beneficial to the operation of the microgrid. The energy storage functioned as the isochronous device on the grid and regulated the operation of the grid, while expending very little of its stored power. The conventional generators on the microgrid operated in droop mode and were thus regulated by the energy storage. This greatly increased the overall reliability of the grid, in most cases the grid operated all day without any failures. The energy storage system even powered the microgrid exclusively for over an hour, with no generators producing power.

This was the first effort to integrate the energy storage into the microgrid. As such, the systems were not optimized. The battery state of charge indicators appeared not to be in proper calibration. It thus was not possible to accurately determine the state of charge of the batteries, and it appeared that the batteries were operating at a level that, although not immediately detrimental, may reduce the battery life. There also appeared to be some software integration issues between the energy storage system and the balance of the grid, which caused a grid malfunction. Perhaps most significantly, the ability of the microgrid to control the energy storage was very limited. The energy storage charged and discharged via its own algorithm, independent of the actions of the microgrid. Ideally, the microgrid should be able to command the energy storage to charge or discharge in order to optimize energy usage by the grid. The generators have an operating point, approximately at 90% of their rating, where their fuel economy is the greatest. If the total demand is less than that, the generator or generators will be operating at less than peak efficiency. Operating at maximum efficiency will generate an energy surplus that may be absorbed by the energy storage for use later. Conversely, if the load is somewhat higher than a generator can produce efficiently, but not enough to warrant another generator to operate, the energy storage may provide the difference.

Corrective actions: A more comprehensive approach to the energy storage software is required.

First, incompatibilities between the energy storage and microgrid software need to be resolved. Next, an expansion of the capabilities of control of the energy storage should be implemented to optimize the overall system.

From Systems Engineering and Integration Team:

- Algorithm did not respond quickly enough to load fluctuations especially in cases where the load fluctuation was greater than the size of a generator connected to the grid. Possible solution is having more spinning reserve, which increases fuel consumption.
- Algorithm for the inverter/battery needs to be improved to address the charge state, chemistry included, of the battery connected to the micro-grid, e.g., optimized charging and discharging, lithium vs. acid, and temperature.
- Faster communications – in cases where communications are not fast enough there needs a way to keep the grid up and running to supply critical loads. Basically, fine tune algorithms, within network constraints, to improve communications.
- Fans were installed in the Tents #1 and #3, with EIO controlled IECUs, to push the return air from the tents into the IECU as a work around because the IECU control box (that interfaces the EIO software) was turning IECUs "OFF" when the temperature set point was reached. The IECUs should be in "VENT" mode after the temperature set point is reached.
- This was the first time putting an energy storage device on the grid. It helped stabilize the grid, i.e., helped hold the voltage and the frequency better than a TQG. However, the inverter had trouble with the clothes dryer on the grid.
- Software version management is key.
- IPD hardware required improvements. Welded a copper bar onto the contact point.
- Automated IECU shut down probably not a good idea. The controller complicated management unnecessarily. Control cable too short to reach into the tent.
- Demonstration gave the Technology Provider a key opportunity to see where improvements are needed.

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B.14 Man-Portable Genset for Power Generation for Expeditionary Small Unit Operations (MANGEN)

TRL: The MANGEN system has been demonstrated in two Technical Support and Operational Analysis (TSOA) events (TSOA 16.2 at Ft Hood, TX and TSOA 16.3 at Muscatatuk, IN) and at the Ft Devens BCIL in support of the SLB-STO-D 50-man camp and 300-man camp demonstrations. The system TRL is 7.

Standardization, Interoperability: The MANGEN platform is a COTS, spark-ignited (SI), engine-driven generator set that has been modified to operate on JP-8, DF-2 and gasoline. Modification is made up of two COTS based, original equipment manufacturer (OEM) independent, scalable "drop in" items - the fuel processing kit (FPK) and a fuel/air metering control software overlay. The FPK includes a fuel conditioner, control board for fuel/air metering, and Li-ion batteries for cold start. It is available from Novatio Engineering Inc. and

their manufacturing partner Fidelity Technologies as a stand-alone module for upgrade or integrated onto an OEM SI engine. The fuel conditioner and the batteries are commercially available items. The software overlay is available through Fidelity. MANGEN systems are available for procurement from Fidelity and through ADS, Inc. They are operationally and environmentally compatible for use with Army Universal Serial Bus (USB)/Squad Power Manager (SPM) chargers, the NSRDEC fuel-fired kitchen, and OACIS, as demonstrated in tactical environments.

Tailorability, Modularity, Versatility, Scalability: The fuel conditioner comes with a mounting plate that is easily tailored with appropriate mounting holes for installation on any COTS SI engine-driven generator set. The software for controlling the fuel/air metering is a simple overlay to the existing genset controls and easily adapted for use on any OEM engine. The FPK uses the same mounting holes as the existing carburetor. The controller and batteries are attached to the side panel of the generator set. The FPK is a scalable design from 500 watts to 2000 watts.

Net Ready: The MANGEN is not intended to be connected to the internet or other communications infrastructure.

Manpower: The MANGEN is to be installed and operated by any platoon/squad/camp Soldier. System will provide full continuous power within 5 minutes of emplacement and application of loads. User level maintenance requires oil change every 50 hours by one operator and typically takes less than 30 minutes. Refueling of unit can be done by any Soldier via fuel can as needed. Hours of operation on a full tank is between 3 to 7 hours (with load ranging from 100% to 0 %).

Personnel Capabilities: MANGEN can be supported with existing platoon/squad/camp personnel in any tactical environment. No specialized MOS is required for the installation, operation and refueling of MANGEN. However platoon/squad leaders/camp commander may require a 91D MOS to change oil. The MANGEN burns very little oil, so only oil changes are required. Developmental efforts to reduce/eliminate oil dilution have been successfully completed. The oil change requirement is increased from every 50 hours to every 100 hours.

HFE, Complexity: The MANGEN is a single-man lift and carry item. It uses a 120 VAC ground fault circuit interrupt (GFCI) duplex outlet and a 24 VDC military specification (MS) connector to enable interface with all military battery chargers, camp lights, laptops, etc. As with any power source, the MANGEN must be grounded via grounding rod. System must be issued with its own ground rod and hammer.

System Safety: The operating voltage of MANGEN is 120 VAC via GFCI duplex outlet and 24 VDC via a MS connector. The MANGEN has several safety devices that protect the unit itself and other military equipment against short circuits, low fuel shutdown, overload, etc. When a safety device is activated, the load is removed until the operator corrects the issue and resets the generator set. The MANGEN provides a full continuous output of 750 WAC from sea level to 4000 feet at 95 °F. A second system design approach provides full continuous output of 600 WAC and 600 WDC. The Rapid Equipping Force has obtained a safety confirmation for the MANGEN 750 W system.

Health Hazards: The MANGEN does not present any health hazards if the user follows the Operator’s and Maintenance Manuals. The MANGEN must be operated outside, not inside shelters. A full list of identified hazards and employed mitigation methods can be found in the Safety Assessment Report (SAR) for the system.

Training: The MANGEN comes with an Operator's and Maintenance Manual and a Training Manual. Documents provide a detailed explanation on how to start and operate the generator set.

Survivability: The MANGEN is designed to start, stop, and operate in extreme tactical environments to include desert, temperate, and tropical climates. The system includes components to protect the system and its loads from normal electromagnetic interference levels present in a base camp. It has not been tested under HEMP conditions. The MANGEN design does not address protection against CBRN event.

Reliability: Three units have been run continuously: 1550 hours, 1600 hours, and 600 hours with no major failure. One unit required a valve adjustment - which is typical for a COTS Honda unit. The projected MTBF is 800 hours which exceeds the required MTBF of 650 hours for platoon power assets.

Availability: MANGEN units are available for procurement through Fidelity and ADS, Inc. They are "ready to go" right out of the crate. Tools found in the standard tool kit used by a 91D can be used to maintain and repair the MANGEN. The unit must be issued with its own ground rod and hammer which will be embedded inside the system.

Maintainability: The MANGEN can be operated for a long period of time through proper maintenance as described in the Operator's and Maintenance Manual. Per the manual instructions, oil should be changed after every 100 hours of operation. The system is designed to provide easy, open access to all internal components for all required maintenance.

Sustainability: The MANGEN requires 5W-30 oil in the Spring, Summer and Fall. 0W-20 oil should be used in the Winter if the temperature falls below 32 °F.

Supportability: The MANGEN requires 5W-30 oil in the Spring, Summer and Fall. 0W-20 oil should be used in the Winter if the temperature falls below 32 °F. Spark plugs and oil for this generator set can be found at local hardware shops, automotive shops or online.

Deployability: The MANGEN is packed in a cardboard shipping box with no fluids (oil/fuel) and transported via air, land and/or rail. This system can also be easily hand carried. The MANGEN exceeds the DOD Capability Needs Analysis 16-20 - Protection requirement for providing electric power to critical systems within 2 hours at theater level by providing power within 5–10 minutes of site arrival and application of loads.

Transportability: The MANGEN is packed in a cardboard shipping box with no fluids (oil/fuel) and transported via air, land, and/or rail. This container can also be easily hand carried. The system must be issued with its own ground rod and hammer that will be housed within the power system.

Impact of Footprint: The MANGEN requires a minimum of 1.5′ x 0.83′ x 1.25′ (1.56 ft^3) of clear, relatively level area for setup. This item can be placed anywhere within the base camp and guard tower sites that requires low-level AC power (battery chargers, camp lights, laptops, etc.).

Cost/Affordability: The cost of the MANGEN is approximately $6500 per unit in a 1500 quantity lot. Costs depend on the quantity and delivery requirements.

Soldier Feedback 1: *Demo 1, BCIL, 50-man camp (542d Quartermaster Company - Force Provider)*

The MANGENs were well received by the Soldiers, who all had many positive things to say about them. All of the Soldiers agreed that the generators are a good idea and described them as "simple, lightweight, and easy to operate." They also said that "anybody could use them… they're easy to use and easy to operate," "easy to move around, not heavy at all," "good for mobility, good for power sources," and "having power as a backup is always a good thing." Soldiers suggested the MANGENs should be employed for duty in locations such as guard towers and motorpools.

The Soldiers then provided some recommendations for improvement. One recommendation was to make the battery external to the system so that it is easily accessible. The Soldiers also suggested adding a weather cover on the front of the system or including a cinch bag that would be able to protect the generator against inclement weather. The Soldiers also thought a whisper quiet mode would be beneficial.

Finally, the Soldiers would like fault indicators for the portable generators as well, such as a diagnostic program on a compact disk to run and diagnose problems. One Soldier explained: "no matter what, there has to be some sort of computer disc with it to see faults. There's always a laptop in the field to hook up to install and find a fault. A USB port would be useful to hook up to a laptop. Maybe even create an app to hook up to check faults."

Lessons Learned 1: *Demo 1, BCIL, 50-man camp*

During the demonstration the Technology Provider uncovered some reliability issues that should be corrected before Developmental Testing. Some systems stalled frequently. One system experienced a failed circuit board. Another had a bent rod causing the generator to fail. And there were a number of incidents attributed to fuel filter issues.

Soldier Feedback 2: *Demo 1, BCIL, 300-man camp (542d Quartermaster Company - Force Provider)*

To begin the MANGEN discussion, the Soldiers were asked to explain when they would use the MANGEN in the field. Some of the possible uses included powering lights (e.g., when setting up a base camp), cell phones, radios, walkie-talkies, and other communications. The Soldiers thought that it could be used both within and outside the wire and that it could be brought to the Tactical Operations Center, motorpool, or on convoys for emergency purposes. Because it is lightweight, the Soldiers also thought the "mobility of it is great" and that "anyone wouldn't mind

carrying it honestly." They thought that being "only" 35 lb and "rucksack friendly," it is something that any Soldier could carry as long as the equipment was cross-loaded to make up for the extra weight of the MANGEN. They thought that having the MANGEN on reconnaissance missions would be beneficial in case communications go down or batteries fail: "rechargeable batteries aren't as reliable as new batteries. The power is known to die quickly"; "Even if you are getting a new battery, they might not be fully loaded."

The Soldiers were then asked if they would potentially carry fewer batteries on a 72-hour mission if they had the MANGEN and if 500 W is the right size. All of the Soldiers said that they would carry fewer batteries, but one Soldier said that the standard number of batteries required for a mission depends on the type of radio being used. Regarding the size of the MANGEN, the Soldiers thought that 500 W would be good for inside the wire, but having the option of a smaller MANGEN (e.g., 250 W) would be good for reconnaissance missions: "I think you have to look at the generator itself. It's going to make noise. You have to look at your loads too, but the smaller the size, the less noise it makes. You're not going to charge 8-9 batteries at once during a recon. If you need to recharge, you can use two. It's mainly just for recharging a couple of batteries every day. If you get smaller, that's going to be less noise. For recon missions, that's important." Although this Soldier expressed his concern about the noise of the MANGEN, most of the Soldiers agreed that the MANGEN is "pretty quiet" overall and that although having a smaller model available for reconnaissance missions would be nice because they would be quieter, the current 500 W MANGEN is still quiet. For maintenance, the Soldiers thought that based on the size of the MANGEN (0.6 gallon tank), they would have to refuel approximately every 5 hours. One Soldier said that it "would be nice to have auxiliary fuel capabilities so you don't have to have someone sitting there pouring a half gallon at a time. You could just plug it in and walk away."

Lastly, the Soldiers were asked about other possible uses of the MANGEN and any recommendations for improvement. The Soldiers said the "possibilities are endless." One Soldier suggested running the OACIS with it and another Soldier suggested "running some of the pumps, which need a generator. Instead of needing a big gigantic generator, you could use the MANGEN." Some of the Soldiers' recommendations for improvement included securing the battery pack and adding mounting brackets for vehicle transport. The Soldiers thought the battery pack needed to be better secured because "on a HMMWV, just the vibrations will make it loose." In addition, all of the Soldiers agreed that it would be beneficial to add brackets that would allow the MANGEN to be mounted to vehicles during transport instead of using ratchet straps to secure it. Additionally, they thought that adding mounting brackets would allow the MANGEN to "become a necessary part of the mission." They thought that it could be left on mounting brackets in the bed of the vehicle because "you never know when you're going to need it" and "it's good to know it's there." If it was always in the vehicle, they would be able to just "start it up and plug it in." They also thought this was beneficial because then there is "no issue with [storing] fuel on the outside of the vehicle because it's [MANGEN] is out of sight."

Lessons Learned 2: *Demo 1, BCIL, 300-man camp*

MANGEN units powered the assigned loads (battery charger, load bank, camp lights) during the duty day. The Technology Provider uncovered some technical issues, especially hardware issues

with the shutter. The vendor repaired or replaced units as necessary and the data collection process proceeded without penalty. Other than the minor technical issues, the units performed as expected. The data from operation of the load bank showed some interesting anomalies. For some runs, the power factors would be different for various steps. This was true of the N750, P600A, and P600B. Neither run with the N1250A or N1250B showed this phenomena. On several occasions a MANGEN unit successfully powered the third-generation OACIS system.

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B.15 Hybrid Power Trailer (HPT)

Final assessment pending submission of attribute data.

B.16 Modular Force Water Generation Storage & Analysis (Water from Air - WFA)

TRL: This system has been demonstrated in field environments. TRL is 6+.

Standardization, Interoperability: The WFA is a standalone system. It uses camlocks to plumb to water storage components. It uses standard JP-8 fuel in its engine and is mounted on a standard military trailer, M1073.

Tailorability, Modularity, Versatility, Scalability: The WFA system is potentially scalable. It can be put in a standard ISO shipping container to increase its rate of water generation 4-5 times.

Net Ready: NA. Currently there is no requirement for this system to operate on a network.

Manpower: Operation of the system requires periodic checks for engine fluid levels. The system requires water quality checks including chlorine, turbidity, pH, and total dissolved solids (TDS) hourly. This could be an automated function. Chemical batching is required. Refueling is required. A reasonable support plan would be to have a 2-man buddy team to cover all water systems in a Force Provider camp.

Personnel Capabilities: No new MOS is required. A Soldier with MOS 92W (Water Treatment Specialist) would be the operator and maintainer. A Soldier with MOS 68S (Preventive Medicine Specialist) would verify operation of the system by taking and analyzing water samples. A Soldier with MOS 91B (Wheeled Vehicle Mechanic) would service the unit's onboard engine.

HFE, Complexity: Demonstration of the system has shown that tasks will be simple for the operator but more complex for the maintainer. The system could be modified and improved. One area that needs improvement is viewing the screen.

System Safety: There are no identified issues with safety of the system. Water hoses will need to be protected from camp traffic, both pedestrian and vehicular.

Health Hazards: This is system is loud. Hearing protection is required. Also, standard personal

protective equipment for chemical handling and fueling is required.

Training: Training operation of the system should be straightforward. Standard engine maintenance training would be required.

Survivability: Currently the system is not hardened and has no degraded modes. However, the system could be hardened to meet typical requirements.

Reliability: The system is expected to meet the reliability requirements stated in the Tactical Water Purification System (TWPS) product description, Jan 2006 - "The TWPS shall have a system hardware reliability of at least 180 hours hardware MTBEFF (mean time between essential function failures)..."

Availability: The system could, if required, run continuously 23 hours per day, with 1 hour of downtime for maintenance and refueling.

Maintainability: The system is expected to meet the maintainability requirements stated in the TWPS product description, Jan 2006 - "The TWPS shall have a MTTR (mean time to repair) no greater than 1 hour for all unscheduled maintenance demands and a MaxTTR no greater than 2 hours for 90% of all Essential Unscheduled Maintenance Demands..."

Sustainability: The system requires fuel, potentially lots of it. The consumables are standard - chlorine, motor oil, engine repair parts. The desiccant will likely have a lifespan of years.

Supportability: This system will a have a few support requirements. Fuel must be positioned near or moved to the system as required. Potable water produced must be moved or directed, i.e., pumped and/or plumbed, to some certified water storage component such as a bladder, container, or trailer.

Deployability: The current system is mounted on a standard military trailer. Will require a prime mover to load and unload. It is heavy — 11 tons, empty, with trailer.

Transportability: The trailer-mounted system is towable by standard military vehicles, either a 5-ton medium tactical vehicle or a HEMTT, while empty. The system could be redesigned to be lighter. The system could also be redesigned to be housed in a container rather than trailer mounted. The objective is to transport with water and produce water on the move.

Impact of Footprint: This system requires space in or near the camp. The trailer-mounted system requires 14' x 8' x 12'. Noise isolation must be considered. The system requires a nearby tank or a pump to direct the water to point of use or place of storage.

Cost/Affordability: $300,000/unit (including trailer).

Soldier Feedback: *Demo 1, BCIL, 300-man camp (542d Quartermaster Company – Force Provider)*

The Soldiers were first asked to discuss at what size camp they could see the water from air technology being used. Most of the Soldiers thought that it would be appropriate for use on a 300-person camp, but that multiple systems could be used at a larger camp to accommodate the large number of resident personnel. Many of the Soldiers believed that the best uses of this technology would be for providing a supplemental backup source of water, or during the initial setup of a base camp: "On a trailer it's efficient. On a new FOB, I like the fact that you can just bring it in and get it rolling." Another Soldier said that "it doesn't hurt to get water from air. The fact that you're getting water from basically nothing is great." When asked who they could see operating the water from air system, some of the Soldiers said water treatment specialists (MOS 92W), while others thought that any Soldier would be able to use it with little to no training because it's "pretty self-sufficient" and "self-regulating." One of the Soldiers said they saw the responsibility of the water from air system "falling on us [92W water treatment specialists] because it's low maintenance and self-chlorinated, it's not that hard for us to take it on, on top of other things."

Some of the Soldiers believed the technology would be good for use as a backup source of water. Another Soldier then explained that "it's better to have it than not" because "you expect resupply to be there, but things happen. It's great to have something where you can flip something on and get water. When you're down range, you don't know when you're getting water. The option to make water within an hour is great." The Soldiers thought that the system was "extremely efficient" because it had the potential to make 7 gallons of water using only 1 gallon of fuel.

Next, the Soldiers shared what they liked best about the water from air system. The main responses included the system's efficiency, mobility, chiller, and novelty of getting water from air. One Soldier said they liked that the system is "not a stationary unit" because "you don't have to wait for a forklift to move it. You can hook it up to a fueling truck and bring it from FOB to FOB if need be, so that's a great aspect of it." Next, the Soldiers said that they all liked the integrated water chiller: "it's a morale booster"; "I love the chiller on it so you can get cold, fresh water. It's not like water sitting in a water buffalo for hours." One Soldier then said "I just like that it's getting water from the air. It's something completely different. It's awesome that you're getting water from nothing." All of the Soldiers agreed that they would feel comfortable drinking water from air.

For the low fuel alarm system, the Soldiers thought that the low fuel warning should come on when there is 25% of the fuel left and the system should shut down when there is 10% of the fuel left. The Soldiers explained that currently the "low fuel alarm won't come on until you're about out of fuel. It needs to come on sooner" so that they have an adequate amount of time to refuel the system because "finding someone [to refuel] can be difficult sometimes." One Soldier said that "I'd want the warning because if the fuel runs out, it automatically shuts off. If it happens to be your main water source at the time, you don't want it to shut off."

Another recommendation that the Soldiers gave was to lower the pressure gauge. The Soldiers thought that the pressure gauge was located too high on the system making it difficult to check

the pressure because they would have to climb up to see it: "if it's pointing down, it's good. For the person operating it, you want to know what that pressure is. Put pressure by the main panel so you don't have to guess"; "The engineer showed us and it is 10 feet high. It's pretty high up there if you're going up and down every day"; "It's not hard to just move it down. All you'd have to do is run a vacuum line down lower. You'd have to make sure the vacuum lines don't have holes, but it shouldn't be hard to move that gauge down." The Soldiers also suggested making the gauge display digital.

Next, all of the Soldiers said that the system should incorporate reusable air filters: "right now they are one-time use air filters, but you might not always be able to get supplies in when you want them or need them. There are manufacturers who make reusable air filters for vehicles. You could just hose them off and reuse them, so you can have two sets" instead of multiple one-time use filters.

Finally, the Soldiers then said it would be beneficial to be able to utilize the system's generator for their other power needs (e.g., jumping vehicles). They shared a few scenarios in which it "would be nice" to have this system in tow with a "multi-purpose" generator.

Lessons Learned: *Demo 1, BCIL, 300-man camp*

The WFA system successfully produced water during the demonstration. For five record runs the WFA operated a total of 31.5 hours, produced about 875 total gallons of water at a cost of 157.8 gallons of fuel, for an average water-to-fuel ratio of 5.5:1. Subsequent to water production for data collection, the Technology Provider ran the system for a few hours in “discovery mode” to check various parameters (such as chlorine content) and procedures (such as the pump out process), and make repairs (fixed a short in the heater circuit created by high humidity environment).

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B.17 Real Time Inline Diagnostic Technology (WATERMON)

TRL: This system has been demonstrated in an operationally relevant environment. TRL is 6+.

Standardization, Interoperability: The system has been integrated with water treatment systems during demonstration. It uses standard collars, etc., for interface. One drawback is that the system is missing certifications.

Tailorability, Modularity, Versatility, Scalability: Need one system per sampling point in the camp. It can be used with any water system and can be used on any size system. The WATERMON is not needed at 50-man camps. Other systems are available for the smallest camps.

Net Ready: The system is missing the necessary certifications. It has been demonstrated in a parallel, isolated network with the same hardware and software.

Manpower: The system requires 1 hour per day. Although its operation is automated, it does require cleaning and calibration no more than weekly (the objective is monthly).

Personnel Capabilities: No new MOS is required. A Soldier with MOS 68S (Preventive Medicine Specialist) would be the reasonable candidate for taking and analyzing water samples. However, this is a low-density MOS and not likely residing at the camp. A Soldier with MOS 92W (Water Treatment Specialist) could be trained to monitor and maintain the system.

HFE, Complexity: HFE considerations are the same as current system Water Quality Analysis Set/Purification (WQAS-P). However, the WATERMON saves man-hours. But, just in case, it would be good to have the manual kit on hand.

System Safety: Chemicals should be properly disposed and not dumped on the ground.

Health Hazards: The proper personal protective equipment will be required when operating the system and handling chemicals. There is a small potential for leaks as currently packaged. This is not unusual for systems of this type.

Training: Training for the SLB-STO-D demonstration and the Network Integration Experiment required 1 hour, including hands on, for operation. Additional training time was required to teach maintenance.

Survivability: This system includes some industrial-quality probes and electrodes, but they are sensitive and fragile. The components are integrated in a Pelican case. There are no degraded modes.

Reliability: Reliability of the system should be comparable to current water monitoring systems.

Availability: The unit would be available 23 hours per day with 1 hour for maintenance daily.

Maintainability: The system would be maintained by the operator. Would take no more than 0.5-1 hour to diagnose and repair.

Sustainability: The consumables and some parts are the same as the WQAS-P and are in the supply system. There is a custom electronics control box that would require new parts provisioning. The probes could be replaced at the operator level.

Supportability: No special tools required beyond what is needed to operate and maintain current water systems.

Deployability: The system can easily ship. There are no hazardous materials. However, calibration consumables must be protected from freezing.

Transportability: The system is housed in a Pelican case and is easily Soldier-portable, about 20 lb.

Impact of Footprint: The Pelican case requires about 8 cubic feet.

Cost/Affordability: Estimated $10,000 per unit.

Soldier Feedback: *Demo 1, BCIL, 300-man camp (542d Quartermaster Company – Force Provider)*

The Soldiers were first asked whether they would feel comfortable drinking water monitored with the WATERMON. The Soldiers said that they would trust the 92W if they said it was safe to drink. When asked if the system requires training, one Soldier responded with no, because it was "nothing they hadn't already done." One Soldier remarked "how easy it was to get the readings was awesome. It was quick and allows us to get the water tested. It didn't involve a graduated cylinder. Got the test done by hooking it up and turning it on." Another Soldier said that the "technology itself is highly applicable to the mission. You can test water anywhere. The system itself does what it's supposed to do." Overall, the Soldiers thought it was a straightforward and simple system to use.

The Soldiers were concerned about if the system is safe to use because they were worried that they could be electrocuted if the system got wet: "It's a container with a couple pipes and two breakers. It needs securing. It's not safe. It's not waterproof. I mentioned about the enclosures of the breakers. National Electrical Manufacturers Association (NEMA) 12 is more standard for indoor. NEMA 3R or NEMA 4X is for outdoor"; "The electrical work concerned me. It scared me if it got wet. It didn't look very safe if you had to touch it. You just connected power to the box. If there was water in there, I could get electrocuted. I'd rather have it plugged in and switch it on because that's safer." This Soldier did not like that they had to plug the system in directly without there being an on/off switch. Another Soldier liked the idea of adding a switch in case of fire: "you can just switch it off so there is no electrical current going through to fuel the fire." Next, the Soldiers suggested adding a digital display to the system so that it does not have to be connected to a laptop or tablet to retrieve data. The Soldiers were aware that the system was in a prototype phase and acknowledged that most of the problems (e.g., electrical work, breaker enclosures, and labeling) they encountered with the system were due to the fact that it was still in prototype form and would likely be fixed in future iterations.

Lessons Learned: *Demo 1, BCIL, 300-man camp*

The Technology Provider was able to learn more about the WATERMON system in an operational setting. Minor hardware and training issues were identified that will inform future development and use of the technology.

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B.18 Rapid Identification and Quantification in Water - Pathogen Monitor (PM)

TRL: Some issues were identified during demonstration. The system is labor intensive to operate and maintain. TRL is 5.

Standardization, Interoperability: No interfaces are required. The system is manually operated. There are adequate commercial sources for the expendables.

Tailorability, Modularity, Versatility, Scalability: The tool can service many systems; only one unit is needed. Quantities would be driven by cost. There are no limitations.

Net Ready: The system works like a cell phone-based microscope with a laptop for the database. Future versions should communicate overall logistics data to a central system and have access to public health databases as well as the Center of Excellence for Geospatial Information Science for water sources.

Manpower: The system requires 45 minutes per sample, three times a day, for a 150-person base camp, although this is not necessarily a linear function. Depends on the operation of water treatment and generation systems. There is currently no capability in the base camp for this task, so this is new work. Schedules would be in accordance with Technical Bulletin Med 577.

Personnel Capabilities: No new MOS is required. A Soldier with MOS 68S (Preventive Medicine Specialist) would be the reasonable candidate for taking and analyzing water samples. However, this is a low-density MOS and not likely residing at the camp. A Soldier with MOS 92W (Water Treatment Specialist) could be trained to take and analyze samples.

HFE, Complexity: The system is hard to use. The filters are difficult to handle. More research and development is recommended.

System Safety: There are no safety hazards to the system.

Health Hazards: There are no hazards beyond the mission itself. Proper personal protective equipment is required for handling water samples and chlorine bleach.

Training: Training should not be difficult for the targeted MOS. Training should take approximately 2 hours plus sufficient hands-on training for certification.

Survivability: The system is not fragile. There is no lens in the microscope. The system is as survivable as the host cell phone. There are no degraded modes for CBRN or HEMP events.

Reliability: During demonstration the system sometimes would get a blurry picture. Resolution of the problem is to retake the picture; same as a cell phone.

Availability: Should be available 22 hours per day, which is standard.

Maintainability: There is no unusual maintenance requirement. Components would likely be replaced rather than repaired.

Sustainability: A parts list could be available - cell phone, holder, consumables, circular filters, etc.

Supportability: Commercial parts are available, but not in the Army supply system (yet).

Deployability: The system is easily deployable. Like other military systems it does have a lithium battery, which is not unusual.

Transportability: There would be no transportability issues in theater.

Impact of Footprint: The system is too small for footprint to be an issue.

Cost/Affordability: $2500/unit (phone, laptop, sample holder, software) for procurement; $25/day operation.

Soldier Feedback 1: *Demo 2, BCIL (542d Quartermaster Company – Force Provider)*

The Soldiers were first asked whether this technology was appropriate for use on a base camp and for what size camp it would be best suited. All of the Soldiers said it would be appropriate to use on a base camp because of its speed and accuracy; however, they also said it is "complex" and "there are a lot of steps and a lot of processes," which would require 1-3 days of specialized training. Although it would require training, the Soldiers liked that it would save time because it did not require shipping samples to a lab. Some of the Soldiers said the technology could be used on any size camp, while others thought the ideal range would be 150-500 personnel. One Soldier said "I probably wouldn't go over 500 because once you get to 500 people, a water person has to take care of the drinking water, shower water, and laundry water and there are lots of tests."

The Soldiers agreed that the WQM (Water Quality Monitor) [PM] system should primarily be utilized by a trained MOS-specific Soldier (i.e., 92S – Shower/Laundry and Clothing Repair Specialist, 92W – Water Treatment Specialist, or 68S – Preventative Medicine Specialist). However, they also said "cross-training is always good" and "it would be best if the whole unit knew how to operate and fix it just in case all the water specialty MOSs had to leave and something broke." For specialized training, the Soldiers said hands-on training is necessary and the training could be conducted during "one of our four-day drills up here." [Editor's note: This unit is a Reserve unit from Pennsylvania and often conduct weekend drills at the BCIL.] The Soldiers said the procedure "didn't look difficult," but "reading through the instructions was more advanced. They were made for someone who really knows what they're doing." These Soldiers suggested making the instructions "more Private-proof," meaning they should be easier for a newer Soldier to read and understand.

Next, the Soldiers were asked whether they believed the system provided accurate results. All of the Soldiers agreed that the system "seemed like it would be pretty accurate." They also agreed that they would feel comfortable showering in water tested with the WQM [PM] system, but would not necessarily feel comfortable drinking it. The only safety concern they shared was "if bacteria is in the water and you drink it."

When asked if an automated system would be preferable to a manual kit, some of the Soldiers thought automation "is the way to go if it can be done accurately," while the other Soldiers were concerned about automation because "if it's automated, how will you catch something [errors]?"

The Soldiers said if it could be automated, the tests should be done more than once to reduce potential errors.

The Soldiers then shared various concerns about durability and using the WQM [PM] system in a field environment. One of their concerns was the difficulty of keeping the light- and heat-sensitive antibodies protected in a field environment. Most of the Soldiers agreed that this technology would be best used indoors because of pollen and sanitation: "everything has to be really clean. I feel like if you're in bad weather conditions, it'll be hard unless you have a building that's clean and enclosed." Their other concerns were "if you messed something up down the line, you've already wasted three hours because you couldn't use the reading" and having results come in on a cell phone. They were concerned about having results on a cell phone because "what if it [the battery] drains? What if there's no charging? Or rain? Then you can't get the results anyway."

Lastly, the Soldiers provided suggestions for improvement to the WQM [PM] system. Their main suggestion for improvement was to make the instructions "dummy proof." The Soldiers said "each step should be very specific and drawn out because everyone learns differently and if you don't do it correctly, it's not going to be as accurate as it's supposed to be."

Soldier Feedback 2: *Demo 2, BCIL (Infantry Squad, 82d Airborne Division)*

The Soldiers were first asked whether this technology was appropriate for use on a base camp and for what size camp it would be best suited. Overall, the Soldiers thought the WQM [PM] was convenient and a good idea. However, they said that as Infantry Soldiers, they would not be the ones using the technology to test water quality. Most of the Soldiers agreed the minimum base camp size this technology is best suited for would be 150 personnel. For the largest base camp this technology could be used, some of the Soldiers thought 300 personnel would be the largest because "higher than that, you're going to have water sanitation and dedicated teams of techs." Other Soldiers thought it would be appropriate for use on a base camp with up to 600-1000 personnel.

During the demonstration, the Soldiers observed a researcher testing water with the WQM [PM] system. The Soldiers were concerned about conducting tests outside because of pollen and "stuff falling on the ground, which probably affects quality, especially if you drop something you need." They thought a lab setting would be ideal for testing with this technology because in a field environment, they would worry about losing required supplies. In addition, the technology would need a ruggedized Pelican case to protect it if used in the field. Following the water testing, the Soldiers were able to look at the WQM [PM] display, but said "I didn't know what I was looking at" and "if there was something on there, I wouldn't know what it was." They explained that understanding the results of testing would come with specialized WQM [PM] training.

All of the Soldiers thought the WQM [PM] system would require at least 40 hours of training and certification because the procedure is not simple enough to follow without training. Most of the Soldiers said a specific MOS would not necessarily be required because they would be able to use the technology with enough practice: "I read through the procedures. I understood it but

some of them I had to read twice. It's not simple, but it's understandable." Although the Soldiers said they could learn to use it, they would still prefer something simpler: "We just need something where you can scoop water in and it tells us"; "For our end, we would need something that just detects it"; "Why can't it be like a pool with strips?"

Next, the Soldiers were asked whether they believed the system provided accurate results. All of the Soldiers trusted that the results would be accurate and would feel safe showering in water tested with the WQM [PM] system. They also said they did not have any safety concerns about using the WQM [PM] system, but thought it should require the use of gloves, eye protection, and an apron.

Lastly, the Soldiers provided suggestions for improvement and discussed the WQM [PM]'s return on investment. Their main suggestions were to make it more user friendly, hand-held, and automated. However, they said that regardless of automation, Soldiers would still need to be trained and certified to use the equipment. Additionally, the Soldiers had concerns about needing a cell phone to use with the WQM [PM] because they don't have access to cell phones in the field. Because of this, they said a cell phone would have to be included with the system. Some of the Soldiers then said they had been issued an iPod Touch in the field and suggested using them for the WQM [PM] system because "we could Bluetooth images to Squad Leaders and have the manual and references put onto it." They said the 40 hours of training "could be eliminated" if there was an app on the phone or iPod Touch that "could tell you what to do and when to do it. Like 'hey, time to put another drop in there.'" At the conclusion of this discussion, one Soldier said that the WQM [PM] should be a "self-contained system" meaning it should not require Wi-Fi or Bluetooth to function because it "needs to work on the premise that we aren't going to have signal." Because of this, he said the phone or iPod Touch would require its own database so that it did not require sending or receiving data via Wi-Fi or Bluetooth.

All of the Soldiers said the system provided a good return on investment because "if we didn't have this, we would have to send it [water samples] to a lab, which requires logistics to send it there and back. If we have this to do it in the field, we can have results in two hours."

Lessons Learned: *Demo 2, BCIL*

WQM-PM was designed for the Graywater Reuse-Forward Osmosis/Reverse Osmosis system product water. The WQM-PM tested the recycled graywater for the target disease-causing organism with limited success in its first field environment test (one failure in eight samples). The field event atmosphere had much pollen landing on the sample pad of the device that blocked the sample flow causing failure (one in eight samples). Also the STO-D testing discovered that this system can misidentify and count pollen particles as pathogens (average false alarm noise 8 counts). The failures and the false counts can readily be addressed as engineering and software improvements. Good news is that the pathogen monitoring analyzed more difficult waters that were not intended in its mission such as untreated graywater and treated blackwater with no significant increase in failure rate (4 failures in 19 samples). Turbidity, the water's cloudiness, was analyzed because it could easily be determined that this would cause failures or false counts, but there is no correlation.

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B.19 Water Conservation Technology (WCT) for Mobile Kitchens & Sanitation Centers

TRL: TRL is 3. Operational technology testing demonstrated need for chlorine residual or equivalent.

Standardization, Interoperability: Army SBIR Enhancement to be complete by 2018 for next-generation system.

Tailorability, Modularity, Versatility, Scalability: Recommendation is one Multi-Function Water Heater (MFWH) and one WCT per Sanitation Center per Kitchen (240 gallons per day).

Net Ready: N/A

Manpower: Installation and setup by four personnel in <30 minutes. Daily operation and safety monitoring by one individual. Maintenance by one individual.

Personnel Capabilities: Support by existing personnel, MOS 92G.

HFE, Complexity: Four-man lift/carry. Change membrane filter and add salt (monthly).

System Safety: 120 VAC (<1 kW). Connectors are color-coded to cabling and water connections.

Health Hazards: Hot water and steam lines; electrical hazard; wastewater hazards (standing water); there is no safety release yet.

Training: Manufacturer provided manuals; recommend New Equipment Training.

Survivability: Designed for food waste and grease. EMI and HEMP yet to be tested, yet unlikely.

Reliability: MTBF yet to be evaluated; typical 30-year life intended. Sanitation center has a reliability requirement in the system specification.

Availability: One system ready-to-go.

Maintainability: Maintenance includes plumbing potable water supply and wastewater disposal; replace filters weekly; check chlorine level; drain for cold storage.

Sustainability: Weekly check for debris and corrosion, replace filter.

Supportability: De-scaler may be needed (monthly). Special tools are included.

Deployability: Minimum single modular appliance position (27" x 36" x 56") per MFWH and WCT.

Transportability: System weight currently exceeds 200 lb, while the program objective is to maintain a single component lift weight below 150 lb.

Impact of Footprint: Minimum single modular appliance position (27" x 36" x 56") per MFWH and WCT.

Cost/Affordability: The cost of the system developed under the Army SBIR Phase II was about $15,000 per unit, while the next generation system being developed under the Army SBIR Phase II Enhancement is projected to cost $11,000.

Soldier Feedback: NA. This system was not demonstrated for Soldiers.

Lessons Learned: NA. This system did not participate in SLB-STO-D demonstration.

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B.20 Graywater Reuse System - Forward Osmosis/Reverse Osmosis (FORO)

TRL: Graywater reuse (GWR) is a capability. FORO is a technology that demonstrates the maturity and performance of that capability. Current TRL is 6.

Standardization, Interoperability: This system uses standard camlock fittings. The water distribution box is similar to the current Shower Water Reuse System (SWRS).

Tailorability, Modularity, Versatility, Scalability: The unit demonstrated at the BCIL was housed in a standard TRICON. It could process 4500 gal/day for a 150-man camp. To scale up and increase the daily capacity, the tank could be moved out of the unit.

Net Ready: NA. Currently there is no requirement for this system to operate on a network.

Manpower: This system can be set up in 4 hours by two persons. Requires 3 hours per day for operation and maintenance, such as filter changes and chemical batching.

Personnel Capabilities: No new MOS is required. A Soldier with MOS 92W (Water Treatment Specialist) would be the operator and maintainer. A Soldier with MOS 68S (Preventive Medicine Specialist) would verify operation of the system by taking and analyzing water samples.

HFE, Complexity: One of the pH probes is hard to get to. Some design changes could make it better.

System Safety: The hoses and bladders must be protected from vehicle and pedestrian traffic.

Health Hazards: The hazards are associated with the chemicals involved. Proper personal

protective equipment (PPE) is required for operators and maintainers.

Training: Training should require about 4 hours. Training will need to include (a) operation of the user interface and (b) execution of the routine maintenance tasks.

Survivability: The system is fairly robust. However, there are no degraded modes for CBRN or HEMP events.

Reliability: This system should be as reliable as the baseline. The forward osmosis stacks had no issues during demonstration. The system should be as reliable as any other advanced system for pre-treatment of wastewater. The system is expected to meet the reliability requirements stated in the Tactical Water Purification System (TWPS) product description, Jan 2006 - "The TWPS shall have a system hardware reliability of at least 180 hours hardware mean time between essential function failures (MTBEFF)..."

Availability: The system is expected to capable of operating 22-23 hours daily. The only downtime should be for regular maintenance tasks. There is no initialization time for this system.

Maintainability: No issues were identified during demonstration. Filters need to be cleaned and/or changed - basket filter first, backed up by two cartridge filters. Chemical batching will be required monthly. Salt addition is required daily. The system is expected to meet the maintainability requirements stated in the TWPS product description, Jan 2006 - "The TWPS shall have a mean time to repair (MTTR) no greater than 1 hour for all unscheduled maintenance demands and a MaxTTR no greater than 2 hours for 90% of all Essential Unscheduled Maintenance Demands..."

Sustainability: The consumables for the system are in the supply chain.

Supportability: There are no unusual supportability requirements.

Deployability: The system is housed in a standard shipping container. The demonstrated TRICON version requires a 10K forklift. There are no hazardous materials.

Transportability: The system is housed in a standard shipping container. The demonstrated TRICON version requires a 10K forklift. There are no hazardous materials.

Impact of Footprint: The footprint for the system is the same as the current SWRS.

Cost/Affordability: $250,000 per unit to service a 150-person camp.

Soldier Feedback 1: *Demo 2, BCIL (542d Quartermaster Company – Force Provider)*

The Soldiers were first asked at what size camp this system could be used and how long a camp would need to be established in order for it to be worth the time investment of setting up the graywater reuse system. They said that because there is a minimum amount of graywater that needs to be in the system for it to continue running, the camp cannot be too small. Most of the

Soldiers agreed that the smallest camp at which it could be used would be a 150-person camp and the largest would be an 800-person camp. The Soldiers did not think there was a minimum amount of time the camp would need to be established in order to use this system because Soldiers "could roll it out pretty quickly" and "setup shouldn't take long at all." The Soldiers said this system is "more beneficial" and would be used more frequently than the wastewater treatment system because it outputs more water.

Both the water and power MOS participants in this group said that any Soldier could run the system because it is "one of the most user friendly pieces of equipment here." They thought it was user friendly because the citric acid, anti-scale, and salt could be added to the system without requiring measurement. The Soldiers said the system seemed "very maintenance free" and "very simplistic" compared to systems that require precisely measuring out the chemicals. Some of the Soldiers said specialized training for this system would not be necessary because "you could read the manual and start-up procedures and be fine." Other Soldiers said a week-long class would be beneficial for learning how to set up, run, and troubleshoot the system. All of the Soldiers agreed that basic operation of the FORO system would not require extensive training. However, the Soldiers also agreed that "if something major happens, it's above us to fix it."

When asked if the 92W (Water Treatment Specialist) MOS should be expanded to include graywater reuse and blackwater treatment, the Soldiers said it could be expanded for graywater reuse because the FORO system is simple to use and would be easy to run in addition to other 92W duties. These Soldiers said, however, that having 92W Soldiers treating blackwater "didn't seem feasible" because they noticed the engineer's difficulties working on the blackwater treatment system and did not think it was a simple enough system. [Editor's note: The blackwater treatment referenced by the Soldiers here is not the Wastewater Treatment-Biological (WWT-BIO) system included in this Selected Technology Assessment. The difficulties the Soldiers observed are not attributable to the WWT-Bio.] The 92W Soldiers in the group said it's "possible to include blackwater, but it's not there yet. If it was more simplistic, but I don't know if it can be." The 92S (Shower/Laundry and Laundry and Clothing Repair Specialist) Soldiers said they often "tag along" with 92W Soldiers to "get familiarization," so although they are not water treatment specialists, they said they "should be a part of that [graywater reuse] because it deals with stuff we're using – it connects to the machines we're using." The 92S Soldiers said they could run this system with "no problems."

Next, the Soldiers were asked if they had any durability concerns with the system being used in the field. None of the Soldiers indicated concerns about durability because it "comes in a self-contained container [TRICON]." They liked that the system came in a TRICON because it's compact and provides easy access to the reverse osmosis components.

The Soldiers did not foresee any safety concerns using the system as long as Soldiers operating and maintaining the system use proper PPE (i.e., gloves, face shield, and glasses). They also said they were confident in the quality of the recycled water coming out of the system: "I would be comfortable showering in it… I'd even drink it"; "If it tested okay, I'd drink it."

Lastly, Soldiers shared their likes and dislikes of the system. The main likes were the simplicity and ease of use of the system, the display, that the system is under low pressure, and that it has "fail safes in place." The Soldiers thought the display on the system was at the "perfect level" and easy to read. They liked that the display "breaks down the entire flow of water" and "shows you what pumps are working and what's not and collects data so you don't have to take it [data] down on paper." They also liked the RO (reverse osmosis) filter system: "If one [RO filter] goes down it would just keep running. It would just bypass that one and use another one as opposed to the machine just not working"; "I like that the RO filters are just regular industrial ones. You'd have them on a yacht or something like that…they've worked for a long time and nothing has happened to them." The Soldiers shared only one dislike of the system, which was related to fitting the chemical tanks. This Soldier suggested having "something universal like a quick disconnect."

Soldier Feedback 2: *Demo 2, BCIL (Infantry Squad, 82d Airborne Division)*

The Soldiers were first asked whether this technology was appropriate for use on a base camp and how they could envision it being used. They said it would be appropriate for any camp that is company-sized (150-personnel) or larger because it recycles water to be reused as non-potable water and therefore reduces the need for water resupply. One Soldier said it could be used when "we're coming out of GWOT [Global War on Terrorism]" because deployed units are "getting much smaller" so it is becoming more difficult to get supplies out to those units. This Soldier said "something like this will change the amount of resources you need because it's a closed loop system. If it's used for shower or laundry alone, you're going to have hardly anything lost." Another Soldier said it could be used for expeditionary forces.

They were then asked how long a camp would need to be established in order for it to be worth the time investment of setting up the graywater reuse system. All Soldiers agreed that they would have to be planning to stay on a camp for greater than 30 days in order to set up and use this system, but would want to "employ it right away so that it could be established with the camp. That way the piping and hosing is done at the same time." None of the Soldiers saw any logistical problems with the system because it is sized to fit inside a TRICON, weighs less than 10,000 lb, and "would be no different than getting a company and their gear out there."

As Infantry Soldiers, they said they would be able to operate the FORO system if they were given "another run down" on the system. One Soldier said "with a system like this, you're not going to worry about quality. You're just using it back in toilets. You just monitor chlorine and you don't need [a water] MOS to test chlorine." The Soldiers said they would be able to maintain the system with "daily PMCS [preventative maintenance checks and services]." And because the water is not potable, they said they could run the system as long as a medic or "water dog" took samples of the water monthly. None of the Soldiers voiced any concerns about the quality of water coming out of the system – they all said they would shower in the recycled water and would drink it if no other water was available.

The Soldiers' main durability concern was the use of polyvinyl chloride (PVC) pipes and rubber hoses in the system: "PVC breaks too easily, just like rubber hosing." The Soldiers suggested not

using PVC and replacing the rubber hoses with reinforced nylon. They were unsure how the system would fare being air dropped, so they suggested drop-testing the system.

Lastly, the Soldiers shared their likes, dislikes, and suggestions for improvement to the system. The Soldiers liked that it's user friendly, simple, "small and compact," "almost a closed loop when utilized with the wastewater treatment system," and "you don't have to measure it [citric acid, anti-scale, and salt] out – you just have to throw it in there and the system draws out what it needs." One Soldier said this system "is going to save money and lives." The Soldiers suggested making the system cheaper and simplifying the technical manual with pictures, stick figures, and stickers inside the doors of the system. They also suggested integrating instructions, start-up, shut-down, and troubleshooting into the graphical user interface (GUI). In response, one Soldier expressed concerns about updating manuals if they are integrated into the GUI. Some Soldiers then suggested only having "basic level" instructions in the GUI (e.g., start-up, shut-down, and maintenance) and that "anything more would be for the monthly maintenance specialists." Another Soldier suggested having the ability to update manuals in the GUI with an SD card.

Lessons Learned: *Demo 2, BCIL*

This system operated as intended. The only issues the Technology Provider had to deal with were a failure of the control module and some adjustments to the chlorine injector. A replacement control module was immediately shipped, received, and installed the next day.

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B.21 Efficient Water Reuse Technologies for COBs (G-WTRS)

TRL: TRL 5 complete. TRL 6 ongoing. The G-WTRS underwent pilot testing (7500 gallons per day) at Construction Engineering Research Laboratory with synthetic graywater over a one-month period in October 2015. The system was not fully automated at that time. The G-WTRS is undergoing assessment in an operational training area. The first assessment occurred over 10 days in June 2016 and another 10 days in Nov/Dec 2016. The system was nearly fully automated for these tests but required daily operator adjustments. Longer term assessments will be conducted throughout FY17 to conclude TRL 6 validation.

Standardization, Interoperability: G-WTRS is a research and development (R&D) demonstrator unit (not a prototype yet) manufactured from commercially available treatment elements (i.e., mechanical screen filter, ultrafiltration membranes, reverse osmosis system, ultraviolet disinfection system, chlorine generating system, pumps, etc.). Some parts of the system were custom made (i.e., biofilter tanks, biofilter backwash tank, ultrafiltration feed tank, etc.); however, these items are simply plastic/steel tanks which can be ordered from a number of vendors specializing in/with capabilities of making custom tanks. The controls for the control panels were also programmed by a third party; however, these controls can also be completed by any knowledgeable controls engineer. Furthermore, the custom-made elements of G-WTRS are unlikely to need repair and do not have to be maintained. All items which must be maintained are commercially available. The G-WTRS should interface without any issues with other field systems (power and water, showers, laundry, toilets).

Tailorability, Modularity, Versatility, Scalability: G-WTRS was built inside a 20-foot ISO shipping container and weighs 20,000 lb. The hutch that holds the influent and waste sump pumps can be stored inside the container during transport and rolled out when G-WTRS is being used. It has not been ruggedized to military specifications yet, but it has been transported by truck, crane, and a Rough Terrain Container Handler (RTCH) without any issues. G-WTRS can also be tailored for different Soldier loads through a simple adjustment of manual controls. G-WTRS can serve anywhere from a small group of people to up to a 1000-personnel group (30,000 gallons/day influent flow rate).

Net Ready: The G-WTRS is integrated with the Deployable Metering and Monitoring System (DMMS) and reports nine parameters to the DMMS console for remote monitoring. The G-WTRS is not expected to utilize any other internet capabilities.

Manpower: The G-WTRS setup and integration with other systems is estimated to take about half a day for two people. Most of the setup time is related to integration with other field systems (hose connections, float switches). Once G-WTRS is set up, it takes one person 30 minutes to an hour to make G-WTRS fully operational. It is required that at least one person on the setup team is trained on operating and maintaining the system, although it would be beneficial to have two people capable of managing any issue that arises. Constant presence of an operator is not required as the system can be monitored from a distance through DMMS. The system is designed to require minimal supervision and should be able to operate on its own for one week at a time, though this has not been demonstrated yet. The previous demonstrations required operator intervention once every 24 hours, but the controls have been adjusted to eliminate this requirement. However, an operator must be available in case an issue arises. Several safety measures are built into the system, and in case a system shuts down due to a safety concern, it will have to be restarted manually.

Personnel Capabilities: A 92W or other MOS should be involved in the system setup and integration with other systems. For operation, the system is designed to operate on its own with minimal supervision for weeks at a time. For periodic troubleshooting, a 92W or similar MOS would likely be required.

HFE, Complexity: The G-WTRS is not yet in final prototype format, particularly with regard to the control panel interface. It has a touch screen, but the screens and controls are not intuitive yet and require hands-on training at this time for any users. HFE was inspected as part of an on-site review by the Army Test and Evaluation Command (ATEC) in October 2015, with some minor issues noted, most of which were corrected. Hose connections are not yet keyed and/or color coded, aside from the 2"/1.5" designation for influent and waste vs. product water.

System Safety: HFE was inspected as part of the ATEC on-site review in October 2015, with some minor issues noted, all of which were corrected. Safety measures were considered during the design of the G-WTRS and several safety features were installed during G-WTRS setup, as well as programmed as part of the controls system. Some of the safety measures are the following: installed a solenoid valve which restricts graywater flow to the influent sump pump when the pump is off, thus minimizing the likelihood of influent sump pump overflow; overriding the influent sump pump controls when the ultrafiltration (UF) filter is treating water

slower than biofilters, thus avoiding biofilter overflow; using a UF influent tank with float switches to keep the UF filter from running dry, which would damage the filter; equalizing flow between UF and reverse osmosis (RO) through the use of a UF product water storage tank; installed an emergency pressure release valve for the high pressure pump; and the product water is automatically redirected to waste when its total dissolved solids concentration is above 150 mg/L and chlorine concentration is below 1 mg/L. Several emergency G-WTRS shut down options are also available, including the manual shut down button on the main control panel and the emergency kill switch, located at the entrance to the G-WTRS container, which can be used to cut the power to G-WTRS. There are several moving parts inside the G-WTRS container which are covered with guards for protection of the user and hot surfaces which are clearly labeled. As far as electrical safety, G-WTRS is powered by 208 volt 3-phase power and all electrical components as well as the G-WTRS container are grounded/bonded. Lastly, the chlorine generator creates an exhaust of hydrogen gas as byproduct which creates a fire hazard. However, the hydrogen gas vent system is installed as part of setup with the bleach storage tank outside in the hutch/cabinet.

Health Hazards: G-WTRS operation presents minimal hazard provided that the operator follows the safety protocol and the instructions listed in operator manual. However, some of the known health hazards to the operator, with the safety protocol solutions, are listed here. It is required that the operator wears safety glasses and hearing protection while inside the G-WTRS container as the interior volume can reach up to 90 decibels during certain operational modes and cycles. Full personal protective equipment must be worn while handling chemicals (i.e., safety glasses, mask, gloves, etc.). There are several moving parts inside the G-WTRS container which are covered with guards for protection of the user and these guards should not be removed while the G-WTRS is in operation. Common sense and some knowledge is required for handling electrical connections and cables. Lastly, several surfaces inside the G-WTRS have potential of becoming hot during operation; however, these surfaces are clearly labeled and should be avoided.

Training: The G-WTRS has an operation manual with detailed descriptions of startup, shutdown, operations, and maintenance. However, training for startup, shutdown, and troubleshooting will likely be required if this system is to be fielded.

Survivability: The G-WTRS interfaces with a field generator and PDISE that provides 208 V 3-phase 60 A service to the system. It was noted during demonstration preparations that loss of power results in some water spillage due to tanks draining. This issue is being addressed by sealing some of the sump tanks and increasing their overflow heights.

Reliability: Studies of the G-WTRS long term performance are ongoing. To date, there have been periodic issues including a pump failure and a sump tank leak. These were corrected within 24 hours with improved components. In general, the system has been able to operate unattended in 24-hour cycles. Filtration component lifetimes are expected to be 90% performance retention for at least one year, including membranes and activated carbon materials. The equipment housings and pumps should last longer.

Availability: The G-WTRS is functional and will be capable of supporting a mission of undetermined length. Lead time for a new G-WTRS prototype would likely be 8 months since it is currently a demonstrator system.

Maintainability: It is expected that hands-on maintenance of G-WTRS would take 1-2 hours every week performed by one knowledgeable person. Custom programing of G-WTRS allows for the system to perform some maintenance of specific treatment elements (i.e., mechanical screen filter, biofilters, ultrafiltration membrane) during the treatment cycle, as well as daily scheduled maintenance, which takes place during the last hour of the 24-hour programmed operation cycle, automatically without any required supervision. After the maintenance is complete, G-WTRS proceeds to treat graywater as normal. Maintenance of G-WTRS requiring action from personnel is limited to hauling out the waste created during the daily maintenance cycle (in the case that a leach field is not available for waste disposal), providing the potable water which will be used by personnel and turned into graywater for G-WTRS treatment, addition of salt to the bleach generator every 4-6 weeks, replacement of liquid chemicals used during the daily backwash (i.e., sodium hydroxide, potassium hydroxide, citric acid) every 1-4 weeks, replacement of coagulant mixture every 1-2 weeks, and occasional replacement of the treatment elements (i.e., ultrafiltration membranes, reverse osmosis membranes) which are only required to be replaced once every few years provided that proper maintenance takes place. All chemicals and parts can be sourced directly from a distributor.

Sustainability: G-WTRS requires the following supplies to operate, which are not already part of the system: graywater storage tank, wastewater storage tank, product water storage tank, electricity, food grade table salt, chemicals (i.e., coagulant, sodium hydroxide, potassium hydroxide, citric acid, sodium metabisulfite). Some of these supplies are already part of a functioning base camp (i.e., graywater, wastewater, and product water tanks, hoses, electricity), while others are readily available for purchase through a distributor (i.e., salt, chemicals). Replacement schedule for these supplies vary. Tanks and hoses must be provided only once. Approximate energy consumption by G-WTRS is 10 watt-hours/gallon of treated water. Assuming a 1000-personnel base with 30,000 gallon/day graywater production and 70% treatment efficiency, 210 kilowatt-hours/day will be required. Replacement schedule for chemicals when operating at max capacity is as follows: 40 lbs. of salt every 7 days, 1 gallon of Ultrasil every 7 days, 5 gallons of citric acid every four weeks, 5 gallons of coagulant every 7 days, and 1.2 kg of sodium metabisulfite every time the system goes unused for more than 96 hours.

Supportability: G-WTRS requires the following supplies, which are not already part of the system, to operate: graywater storage tank, wastewater storage tank, product water storage tank, water hose, electricity, food grade table salt, chemicals (i.e., coagulant, sodium hydroxide, potassium hydroxide, citric acid, and sodium metabisulfite). Some of these supplies are already part of a functioning base (i.e., graywater, wastewater, and product water tanks, hoses, electricity), while others are readily available for purchase through a distributor (i.e., salt, chemicals). All these supplies must be installed prior to G-WTRS operation. Upon arrival on site, G-WTRS requires installation, which is estimated to take 4 hours to complete by two personnel, one with training on system installation. Once installed, G-WTRS can be operational within 2 hours.

Deployability: G-WTRS can be fully packed into a 20-foot ISO shipping container, measuring 20' x 8' x 8.5', which is suitable for land, air, and rail transport. The G-WTRS container can be handled by a RTCH. Water, salt, and chemicals required for G-WTRS operation can come packed as part of the system and do not have to be transported separately.

Transportability: G-WTRS can be fully packed into a 20-foot ISO shipping container, measuring 20'x8'x8.5', which is suitable for land, air, and rail transport. The G-WTRS container can be easily handled by a RTCH. Water, salt, and chemicals required for G-WTRS operation do not come packed as part of the system and have to be transported separately.

Impact of Footprint: The physical footprint of the system is relatively small, the whole system fitting into a 20-foot ISO shipping container. A hutch which holds the influent and effluent sump pumps is stored inside the G-WTRS during transport and is positioned next to the container during G-WTRS operation. The vestibule in front of the G-WTRS also holds a UF product water tank and a recirculation pump. Considering the G-WTRS container, the hutch, and the vestibule, but excluding any other tanks or hose located outside of the G-WTRS, when in operation the full system has a footprint of approximately 25' x 12'. The system must be positioned near the shower, laundry, and latrine facilities. If this positioning is not possible, there must be a way to transport/pump the graywater to G-WTRS for treatment and the treated water from G-WTRS to the shower, laundry, and latrine systems for use.

Cost/Affordability: The estimated cost for a G-WTRS prototype at production scale is $300,000 per unit.

Soldier Feedback: This system has not yet been demonstrated for Soldier feedback.

Lessons Learned: This system was the product of an R&D program funded by ERDC that developed bench scale solutions and integrated them into a pilot unit that could be readily scaled up to field assessments. This process was fairly successful, though longer term assessments and automation optimization at TRL5 would be advisable in the future, as these are more difficult to execute efficiently in the field environment. Due to the research focus of the program, the focus on delivery of a final prototype quality product was not the goal. However, it would have been useful to consider issues like the controls interface in more detail earlier to ease transition to field assessments.

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B.22 Exploration of Water Demand Reduction Technologies – Showerheads (WDR-S)

TRL: TRL 7. COTS item. Ready to transition to PM.

Standardization, Interoperability: Identical to incumbent, no issues.

Tailorability, Modularity, Versatility, Scalability: Identical to incumbent, but also exhibits flow rate and spray pattern adjustment.

Net Ready: N/A

Manpower: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

Personnel Capabilities: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

HFE, Complexity: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

System Safety: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

Health Hazards: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

Training: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

Survivability: Selected technology does not degrade base camp or Soldier survivability.

Reliability: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

Availability: To be determined if market inventory would support an immediate retrofit of Force Provider containerized systems and the 12-head shower systems.

Maintainability: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

Sustainability: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

Supportability: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

Deployability: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

Transportability: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

Impact of Footprint: Low-flow showerhead properties are identical to incumbent showerhead for this attribute.

Cost/Affordability: Increase in cost per unit is likely, but the return on investment is expected to be less than 6 months.

Soldier Feedback: Soldiers were not surveyed on their experience. Data on shower duration indicates that Soldiers took shorter showers with new showerhead.

Lessons Learned: *Demo 2, BCIL*

A showerhead change may not be perceivable to the user, therefore allowing for a readily acceptable improvement that may result in a potable water consumption reduction. During demonstration it was found that the quality of water in the showerheads makes a difference in flowrate. Debris in the filter affects the flow. The low-flow showerhead uses an aerator; the baseline uses a restrictor.

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B.23 Solid Waste Destruction System - Altex Technology Corp (SWDS-A)

TRL: SWDS-A prototype is TRL 5 as of October 2016 with no current funded effort to improve maturity. The prototype met most of its performance goals. Improvements desired include a shortened warm-up procedure, control automation, improved feedstock loading, and improved ash removal. The system shows much promise as an alternative to small incinerators, and NSRDEC is actively pursuing follow-on funding sources to reach TRL 6.

Standardization, Interoperability: Little to no standardization with respect to parts and supplies already in the Army supply chain.

Tailorability, Modularity, Versatility, Scalability: The SWDS-A as a system is not easily tailorable, modular, versatile, and scalable. Scaled for 150-man camps, scalability would be accomplished by fielding multiple systems.

Net Ready: Not an information system.

Manpower: Requires one operator; potential for part-time with automatic feed system.

Personnel Capabilities: Intended to be supported by the same personnel that would support a small incinerator. Current concept is to be organically supported. System is comparatively simple.

HFE, Complexity: Operation is simple with little human-system interface, e.g., add waste, remove ash daily, automated startup and shutdown. Maintenance and repair promise to be minimal due to the simplicity of the system.

System Safety: Under normal operation, automated controls would mitigate hazards to the system. System cannot prevent unsuitable feedstock, e.g., unexploded ordnance or hazardous materials.

Health Hazards: Under normal operation, operator is not exposed to health hazards aside from contact with the solid waste feedstock. Maintainers are potentially exposed to hazards including carbon monoxide, combustion or explosion hazards, and high temperatures. These hazards can be mitigated by personal protective equipment, lockout/tagout, and other safety procedures.

Training: Training materials can be easily developed.

Survivability: Not expected to degrade base camp or Soldier survivability.

Reliability: System is not mature enough to assess reliability. Due to the simplicity of the system, it has potential to be very reliable. There are instruments subject to degradation, e.g., thermocouples and oxygen sensors, which would need periodic replacement.

Availability: System is not mature enough to assess availability.

Maintainability: System is not mature enough to assess maintainability.

Sustainability: System can support sustainability by disposing of solid waste with minimal fuel investment, and order of magnitude or more less than a small incinerator.

Supportability: The system requires very few consumables by design. Requires fuel for startup and make-up heat for low-energy feedstock. Current max consumption is 1.5 gallons per hour. Potentially requires seals and gaskets, thermocouples and other sensors.

Deployability: Packaged in two TRICONs for transportation. Final version would be qualified to meet all Force Provider transportation requirements.

Transportability: Design intent is to meet requirements of Force Provider transportation assets including onsite materiel handling equipment at the 150-man camp.

Impact of Footprint: As currently configured, the system transports as two TRICONs. Deployed footprint on the order of 500 ft^2. Requires space for solid waste transfer and storage, e.g., bins, dumpsters, or similar. Requires proximity to electrical power source, max 1-2 kWe.

Cost/Affordability: Predicted production cost is less than $250,000.

Soldier Feedback: This system has not yet been demonstrated for Soldiers.

Lessons Learned: Not part of SLB-STO-D integrated demo. Demonstration at Altex showed promise and achieved most of the Phase II performance objectives. The startup time is the single largest liability in need of improvement.

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B.24 Battalion Waste-to-Energy Converter (WEC)

TRL: WEC prototype is TRL 5 as of October 2016 with expectation that it can reach TRL 6 by the end of December 2016 through demonstration at Fort Benning. WEC is an upgrade of the "Green Energy Machine" (GEM), which reached TRL 6/7 at Edwards Air Force Base. Control system requires more development for stand-alone unattended operation.

Standardization, Interoperability: Little to no standardization with respect to parts and supplies already in the Army supply chain. Many major subsystems, e.g., shredder, drier, destoner, pelletizer, gas filtration, and power generator, are COTS or COTS-based systems.

Tailorability, Modularity, Versatility, Scalability: The WEC as a system is not easily tailorable, modular, versatile, and scalable.

Net Ready: Not an information system. Would need to be compatible with the microgrid with which it interfaces. Not currently configured for a microgrid.

Manpower: Requires a minimum of one full-time operator at all times, possibly two. Current concept is to be supported by Logistics Civil Augmentation Program (LOGCAP) contractor.

Personnel Capabilities: LOGCAP contractor supported. Typical activities include: daily starting and stopping of the system (assuming it is not run continuously); loading solid waste into conveyor or hopper while removing obvious problem feedstock like batteries and large metal items; daily emptying of char/ash drum(s) and removal of tramp materials, e.g., metal, glass, rocks, from destoner; and refueling the bi-fuel diesel generator.

HFE, Complexity: Operation is simple with little human-system interface, e.g., add waste, remove ash daily, automated startup and shutdown. Maintenance and repair can be relatively complex due to the number of subsystems, similar to a ground vehicle.

System Safety: Under normal operation, automated controls can mitigate hazards to the system. System cannot prevent unsuitable feedstock, e.g., too much moisture, hardened metals, unexploded ordnance, etc., but can safely shut down in most circumstances.

Health Hazards: Under normal operation, operator is not exposed to health hazards aside from contact with the solid waste feedstock. Maintainers, however, are potentially exposed to many hazards, including high noise levels, carbon monoxide, combustion or explosion hazards, high temperatures, hazardous energy, cutting devices, high speed machinery, etc. These hazards can be mitigated by personal protective equipment, lockout/tagout, and other safety procedures.

Training: Training materials can be easily developed. LOGCAP contractor supported.

Survivability: Not expected to degrade base camp or Soldier survivability.

Reliability: System is not mature enough to assess reliability. Due to the number of complex moving parts, plus instruments subject to degradation, e.g., thermocouples and oxygen sensors, frequent minor repairs are expected.

Availability: System is not mature enough to assess availability. Design availability is 0.86 based on up to 24 hours a day, 6 days a week operation, with a day reserved for weekly maintenance.

Maintainability: System is not mature enough to assess maintainability. Design average maintenance is 2 hours/day (averaged out over a year, factoring in larger maintenance). Maintenance requires a skilled mechanic. Weekly maintenance includes: visual inspections, greasing bearings, tensioning bolts and belts, replacing filter bags, removing bottom ash, tightening packing seals and cleaning ports, and inspecting and cleaning syngas intake manifold. Monthly maintenance includes: cleaning dryer bed and conveyor areas, checking sharpness of shredder blades, and inspection of heat exchanger tubes, bolts, fire suppression heat sensors, insulation, flanges, chains, and pneumatics. The generator has additional monthly maintenance requirements: replacing engine oil, replacing syngas filters, and inspecting spark plugs, intake manifold, and exhaust system. Beyond that, there are many longer term maintenance activities required for the system and its generator.

Sustainability: System can support sustainability by disposing of solid waste and generating electrical power.

Supportability: Consumables include lubricants and greases, filter bags, char/ash bags, seals and gaskets, thermocouples and other sensors, plus the usual engine/genset consumables including diesel/JP-8 fuel.

Deployability: Packaged in ISO containers for transportation. Final version would be qualified to meet all Force Provider transportation requirements.

Transportability: Design intent is to meet requirements of Force Provider transportation assets including onsite materiel handling equipment.

Impact of Footprint: System will transport as three or four 20-foot equivalent units, i.e., 8′ x 8′ x 20′ ISO containers. Deployed footprint on the order of 1800-3000 square feet. Requires space for solid waste transfer and storage bins, dumpsters, and roll-offs. Required proximity to microgrid or similar electric demand to make use of generated power (transmission distance ~300 feet at 280 V).

Cost/Affordability: Predicted production cost is $1,000,000.

Soldier Feedback: N/A. This unit was not yet demonstrated for Soldiers.

Lessons Learned: Not part of SLB-STO-D integrated demo. Demonstration at Fort Benning indicates that the system is less robust and mature than claimed by the contractor and that more time should be devoted to shakedown and commissioning in the future.

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B.25 Wastewater Treatment-Biological (WWT-Bio)

TRL: This system has been extensively demonstrated in field environments - Fort Leonard Wood, Fort Bliss, and Fort Devens. TRL is 6+.

Standardization, Interoperability: This system uses standard camlock fittings. The next version of this system should use standard power connections.

Tailorability, Modularity, Versatility, Scalability: The system demonstrated was housed in a TRICON and could process over 2500 gal/day, dependent on wastewater strength. This size would be suitable for a 150-person camp. The system is scalable to larger sizes. The vendor has a version of this system housed in a 20-foot ISO container.

Net Ready: NA. Currently there is no requirement for this system to operate on a network.

Manpower: This system can be set up in 4 hours by two persons. (Note: The system is not necessarily operational in 4 hours. The biomass requires time to mature.) The system requires some daily checks, approximately 2 hours/day for operation and maintenance.

Personnel Capabilities: No new MOS is required. A Soldier with MOS 92W (Water Treatment Specialist) would be the operator and maintainer. A Soldier with MOS 68S (Preventive Medicine Specialist) would verify operation of the system by taking and analyzing water samples.

HFE, Complexity: The system is not overly complex. It requires a ladder to reach over the system and skim the top of the treatment tank. Installing the dissolved oxygen (DO) probe requires a ladder. Either of these tasks could be improved with simple engineering redesigns.

System Safety: The hoses, bladders, and wet wells must be protected from camp traffic, both pedestrian and vehicle.

Health Hazards: The current hazards associated with the system are (a) the requirement to climb a ladder and (b) the standard wastewater exposure hazards.

Training: The system is simple to operate and standard Army training protocols would be followed. Training could be accomplished in about 2 hours, then reinforced with practical exercises.

Survivability: The system is fairly rugged. The current vulnerabilities are (a) fragility of the ultraviolet (UV) light for sterilization and (b) the exposure of wires that could be caught in the container doors. A simple redesign could protect the wires. There is currently no protection or degraded modes for CBRN or HEMP events.

Reliability: This simple system should have a fairly high reliability; "92%". The system is expected to meet the reliability requirements stated in the Tactical Water Purification System

(TWPS) product description, Jan 2006 - "The TWPS shall have a system hardware reliability of at least 180 hours hardware mean time between essential function failures..."

Availability: The system is expected to operate continuously once the biomass has initialized.

Maintainability: The system is not overly complex. The pumps and blowers are maintainable. The system is expected to meet the maintainability requirements stated in the TWPS product description, Jan 2006 - "The TWPS shall have a mean time to repair (MTTR) no greater than 1 hour for all unscheduled maintenance demands and a MaxTTR no greater than 2 hours for 90% of all Essential Unscheduled Maintenance Demands..."

Sustainability: The UV light is potentially fragile and replacements will need to be on-hand or readily available. The DO probe is fairly robust.

Supportability: No special tools are required.

Deployability: The system is housed in a standard shipping container. The demonstrated TRICON version requires a 10K forklift.

Transportability: The system is housed in a standard shipping container. The demonstrated TRICON version requires a 10K forklift.

Impact of Footprint: The system requires space for the TRICON container and wet well tank. System must be set up 100 meters from living/work/kitchen areas. The system also requires destination for effluent - leach field, lagoon, natural water body, etc.

Cost/Affordability: Estimated $100,000 for TRICON unit.

Soldier Feedback 1: NA. Soldiers were not exposed to the WWT-Bio during the first demonstration at CBITEC.

Soldier Feedback 2: *Demo 1, BCIL, 300-man camp (542d Quartermaster Company - Force Provider)*

The Soldiers thought that the user interface of the system was "on point" because it was centralized and "had all the information you need." They also thought the system "did what it said it would do" by turning blackwater into graywater and eliminating solid waste. However, they believed that the benefits of the system did not outweigh the negatives/risks of the system and provided some recommendations for improvement.

Some of the risks that the Soldiers raised were in regard to the wastewater treatment system. They said the water reservoir could act as a breeding ground for mosquitos, flies, and parasites. In addition, they were concerned about the system's placement on the camp and worried that it could spread disease if placed in close proximity to the DFAC (dining facility). Because the system did not have a cover, the Soldiers were also concerned that it could overflow or that they might find dead animals or "disease-ridden" mosquitos in it: "it's a dumpster pretty much. The

safety hazards are way too high"; "We know mosquitos carry horrible diseases. Do you want to put Soldiers in danger on their own FOB? We're trying to minimize the dangers of Soldiers overseas. Breeding diseases that close to the DFAC just gets to me." Because the system would receive an intake of blackwater from the DFAC, the Soldiers were concerned that having the system near the DFAC would be a safety hazard. To mitigate some of these problems, the Soldiers suggested adding a cover with an exhaust and air filtration system "because all of the blackwater fumes and particles are in the air and besides touching it, that's what gets people sick."

The Soldiers were also concerned about the safety of the Soldiers who would be maintaining the system and what illnesses they may be exposed to: "You have to think about the Soldier working with it. That's a higher risk to get disease"; "For a Soldier to go up there on a daily basis, their quality of life… I feel bad for the Soldier." In order to reduce the necessity for a Soldier to work directly on the system, one Soldier thought it would be a "huge plus" to add an automated machine that would skim the waste instead of requiring a Soldier to manually do it.

The Soldiers said that the system "definitely needs a bubble level" because they do not want any risk of the system tipping over on uneven ground. Next, the Soldiers said that the standard of graywater coming out of the system needs to be brought up so that it can be put through the graywater reuse system. Their last recommendation was that there needs to be a way to clean out the system when it is not in use: "Have a way to clean out the inside and be able to store it. If it's going to be stored for a long period of time, how do you get all the sludge out?"; "I don't see the cleaning capabilities of the inside of it. How do you clean it out before you transfer it? It'll just build up."

Lessons Learned 1: *Demo 1, CBITEC, 1000-man camp*

The system operated continuously at the Fort Leonard Wood Wastewater Treatment Facility during the period 12 March-20 April 2015. The following lessons are derived from the operator's routine reports:

- The system was set up on 10 March 2015. The UV light apparently broke during shipment. It was replaced.
- There were periodic checks the first few weeks but no regular reports early on to indicate the status of the system. Then on 1 April the operator reported "the microorganisms in the dBBR [Editor's note: This is the vendor's acronym for the system. It stands for Deployable Baffled Bioreactor.] are growing and all the different bacterial systems are maturing or established and are thus more effective."
- Noted the dBBR effluent pump was not working properly. After some system analysis it was discovered that the low water influent float was tipped over in its hookup on the dBBR door. The operator secured the float in an upright position and the systems began to work properly. There was sample effluent in the collection jug, so it appears the float became dislodged from its supported position on the door sometime on the previous day. This event allowed the operator to examine a low flow probability that could happen on a base camp resulting from minimal water input or loss of power to the system. The low-flow float was now secured on a steel rod next to the equalization tank.

- The operator experimented with different flow rates, noting “dBBR will continuously operate at 2000 gpd (gallons per day) flow rate until next Monday. After sampling on next Monday, it will increase to 6000 gpd, to test shock loading effect. We hope this 6000 gpd event will last for 3 days. After next Thursday it will be switch back to the normal 3000 gpd flow rate.”
- Noted perhaps a few species of water fleas growing in the internal settler and even a few in the final clarifier. The water in the latter tank is moving too quickly to discern the movement of the fleas from the amount of small material swirling in the water.

Lessons Learned 2: *Demo 1, BCIL, 300-man camp*

This system was the same unit that had been successfully demonstrated at Fort Leonard Wood during the period March-April 2015. During that demonstration this unit was set up at the Fort Leonard Wood Wastewater Treatment Facility. It processed 3000-6000 gallons of waste water per day during that demonstration. The second demonstration was at a much lower capacity. And there were a number of issues related to the unrealistic nature of the wastewater that fed the system. The operator noted specifically:

- Limited wastewater available to the system.
- Limited food or organics to generate adequate biological activity.
- Possible anaerobic wastewater fed to the system from the sewer.

In spite of the issues with the influent, the Technology Provider still learned a number of valuable lessons during the demonstration. The following are paraphrased from the operator’s report:

- Biological systems require influent to be effective, i.e., sufficiently “rich,” to be able to treat the wastewater.
- When graywater versus blackwater (or seed sludge) is the predominant food source for the bioreactor, it takes almost three times longer for the biomass to mature.
- Keep the control panel closed or completely opened while monitoring the system to avoid hitting your head when bending below that level.
- Although a variable frequency drive (VFD) primary pump setting is recommended in the reference guide, the water level and head pressure in the wet well is a huge factor for the influent flow rate. The operator must find an optimum VFD setting for the primary pump to maintain an average flow rate of 4.6 gallons per minute (gpm) and not exceed 8 gpm during any 30-minute span. Using the 7-8 foot wet well, the flow fluctuated from 0 to 14 gpm when the VFD setting was set to 32.00. The flow may also be dependent on the solids contents, the height of the water level, or air in the feed line. It was difficult to find a consistent setting to maintain this flow with the current wet well setup. It is suggested to raise the low level float switch to about the 100-gallon graduated level to avoid 0 gpm entering the system. The other alternative is to use a different wet well configuration.
- The dissolved oxygen set points should be adjusted based on influent strength.
- Effluent disinfection may need to be increased or augmented for effectiveness.
- The manufacturer should consider adding Plexiglas sheets with lids (or equivalent) to cover the top of the system to avoid foam-overs and exposure of the wastewater to animals, foreign objects, and attendants.

- The manufacturer should consider a mechanical method for skimming the Internal Settler and Final Clarifier tanks toward a trough or some path that leads to the anoxic zone or sludge drain that occurs at a set frequency.
- The manufacturer should add a level indicator to show when the system is level during setup and operation.

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B.26 Sustainable Technologies for Ration Packaging Systems (STRPS)

TRL: The paper straps for the coated Meal, Ready-to-Eat (MREs) have been demonstrated with testing at the Logistics Support Activity, Tobyhanna, PA. These items were demonstrated and displayed at the BCIL in June 2016 in support of the SLB-STO-D. TRL is 6. (The corrugated pallets and the biodegradable stretch wrap were a "No Go" in this Combat Feeding Research and Engineering Program.)

Standardization, Interoperability: The straps can be commercially available components from M.A. Industries, Inc., that come in different paper strengths, widths, and thickness.

Tailorability, Modularity, Versatility, Scalability: The straps are constructed and can be tailored to the width, thickness, and color needed for the military.

Net Ready: NA

Manpower: The straps are easily removed from the cases/pallets with scissors or a knife, or can be slid off. No additional manpower is required.

Personnel Capabilities: These straps would replace existing straps, so there would be no issues.

HFE, Complexity: The straps must meet the performance specification for the military.

System Safety: There are no safety concerns with the straps.

Health Hazards: NA

Training: Utilizing new straps on the container requires no additional training than that for the existing Meal Bag and fiberboard container.

Survivability: The survivability will be the same as the current straps.

Reliability: These items will have the same performance as the existing straps.

Availability: These items can be readily available.

Maintainability: No maintenance is required.

Sustainability: The straps could be biodegraded.

Supportability: The straps protect the containers that protect the food.

Deployability: These items can easily be deployed just like the existing straps.

Transportability: These items will be less weight than the existing packaging.

Impact of Footprint: Two straps go on each case and then strapping is used for the pallet.

Cost/Affordability: The paper strap is less expensive than the current strap.

Soldier Feedback: Positive Soldier Feedback was received in the focus group at the BCIL supported by SLB-STO-D.

Lessons Learned: Biodegradable polymers are still just too expensive for Army needs.

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B.27 Ration Packaging Reconfiguration (RPR)

TRL: The thermoformed meal bag and the coated corrugated container for the MRE have been demonstrated in conjunction with the Environmental Security Technology Certification Program that funded lightweight and compostable packaging for MREs. These items were demonstrated and displayed at the BCIL in June 2016 in support of the SLB-STO-D. TRL is 6.

Standardization, Interoperability: Thermoformed meal bags and coated corrugated fiberboard are manufactured from commercially available components, e.g., polymeric film and corrugated fiberboard, and utilize film from Phoenix Chemical Inc. and coated paper from Spectra-Kote Corporation. The thermoformed bags can be made at AmeriQual and the fiberboard containers can be made at most corrugators, as long as they accept the coated paper, i.e., York Containers.

Tailorability, Modularity, Versatility, Scalability: The Meal Bag is constructed with a bottom and top film, and a horizontal form fill seal process is used with the ration components. Then 12 meal bags are placed in the corrugated containers. There is Case A and Case B. The fiberboard containers are fabricated on a corrugator in production using the coated paper. A liner is added to the container and is also produced on a corrugator. The weight of paper, flute construction, amount of coating, and glue for containers were all optimized for the production trials.

Net Ready: The Meal Bags and containers do not involve the Internet or other communications infrastructure. There is a Time-Temperature Indicator (TTI) on the cases that links the quality of the ration to the time and temperature since it's been packed, but this feature is not networked. Therefore this attribute does not apply to this technology.

Manpower: The Meal Bag and fiberboard container are purchased by the co-packer and assembled there. There are three co-packers and this is a labor intensive task to assemble all 24

menus of rations into case A and case B. Co-packers will need to make some modifications to their equipment, including the gluing process. There is no change to Soldier manpower required.

Personnel Capabilities: The Meal Bag and the fiberboard container can be supported with existing personnel. Utilizing these items requires no specialized skills to open or use.

HFE, Complexity: The Meal Bag and container must meet the performance specification for the military. These items utilize less material and are lighter-weight packaging.

System Safety: The Meal Bag and the fiberboard container are safe items with no safety concerns.

Health Hazards: The Meal Bag and fiberboard container introduce no new health hazards. There are similar hazards to legacy fiberboard when burning. NSRDEC has a comprehensive report.

Training: Utilizing the new Meal Bag and the fiberboard container requires no additional training than the existing Meal Bag and fiberboard container.

Survivability: The survivability will be the same as the current ration packaging.

Reliability: These items will have the same performance as the existing packaging and are reliable for the warfighter to receive safe food.

Availability: These items can be readily available, but the Meal Bag cannot currently be made by two of the three MRE co-packers.

Maintainability: No maintenance is required.

Sustainability: The container is approved by the Fibre Box Association as recyclable. The containers have been shown to survive transportation studies and perform the same as the existing container.

Supportability: The Meal Bag and container are ready to be opened by the warfighter and the food has a 3-year shelf life.

Deployability: These items can easily be deployed just like the existing containers. Air drop studies have been done for the containers and rough handling testing has been done for Meal Bags and containers together. All food was safe after these tests.

Transportability: These items will be less weight than the existing packaging and since the delivery of rations on trucks weigh out before cube out, more rations could be delivered at once.

Impact of Footprint: The Meal Bags are placed in the fiberboard containers (cases). There are 48 cases per pallet. The pallet is 40 by 48 inches.

Cost/Affordability: The Meal Bag is made with more expensive polymers, but thinner. Cost analysis will be done for this new Meal Bag. The corrugated container is less expensive by a few cents. Need to look at the difference in weight to see how it impacts pallets and trucks. Trucks currently weigh out before they cube out. May be same for air transport.

Soldier Feedback: *Demo 2, BCIL (Infantry Squad, 82d Airborne Division)*

The Soldiers first compared the current MRE box to a new corrugated MRE box. They were asked to share any differences they noticed between the boxes. The Soldiers' initial observations were that the new box may be more water resistant than the current MRE box, the new box is corrugated, and the new box is harder to open. All of the Soldiers agreed the new box was harder to open and said it was harder because it's thicker, has more glue, and they were unable to get their fingers underneath the box's flaps to pull the box open. The Soldiers also noticed that the new MRE box may be able to fit more MREs than the current box and said a dozen MREs per box is "perfect per box" and "perfect for patrol" because they would need three boxes per platoon. One Soldier then said he thought the new corrugated boxes would be harder to stack than the current boxes. Once the Soldiers were told about the weight difference of the boxes, most of the Soldiers agreed that the new box should be used due to its lighter weight, provided it can be made easier to open.

The Soldiers then discussed ways in which they reuse the current MRE boxes. Most of the Soldiers said they are primarily reused for trash or ammo boxes. One Soldier said he stacked some boxes and used them as a "foot locker" and to store socks. All of the Soldiers agreed that reusing the new corrugated box would "probably last longer" than the current MRE box because it has "better structural integrity."

Next, the Soldiers compared the current MRE bags to a new MRE bag. A majority of the Soldiers said the new MRE bag was easier to open, while two Soldiers said the current MRE bags were easier to open. When opening the bags, some Soldiers used their hands, some used their teeth, and some used knives. One Soldier said he would typically be able to open an MRE bag with his teeth, but was unable to open the new bag with his teeth. The Soldiers who thought the new bag was easier to open said it was because the clear packaging is "not as slick as the brown." One Soldier then said the "best combination" would be the current MRE bag made clear because with a clear bag, "you can see what you're getting." Another Soldier said he would be concerned about opening the new MRE bag if it were wet and was also concerned about the new packaging getting brittle in cold or hot temperatures. Next, the Soldiers remarked that the new MRE bags are smaller, which they liked because they could fit more in their rucksacks. Some of the other Soldiers said that although it's nice the bags are smaller, "it's not going to make that big of a difference because we will field strip it." One Soldier then said a benefit of the current MRE bag is they can reuse it once they field strip the MRE. They said once field stripped, they could fit 3-4 meals into a single MRE bag.

The Soldiers then discussed additional ways in which they reuse the current MRE bags. All of the Soldiers said they reused it at some point, mainly for trash or for medical emergencies (e.g., chest wounds). Due to the way the new MRE bags are sealed around the sides, some of the Soldiers peeled them open such that the top and both sides were opened. Because of this, they

said the new MRE bag could not be reused in the same way because once opened, it cannot hold trash or other items unless only the top is torn. One Soldier who preferred the current MRE bags suggested vacuum sealing the current bags in the same way as the new bags are.

Lastly, the Soldiers provided their suggestions for improvement to the MRE packaging. These suggestions included using the new MRE boxes with the current MRE bags and perforating the new box liner to make the box easier to open. One Soldier said "if we access it [new box] from the bottom, it's hard to rip it out from underneath. If it's perforated, it'll be easier to get free." Another Soldier said "don't get rid of the liner because I'd use it as a sleeping mat or as knee pad inserts." Their other suggestions were to make the box easier to open by using less glue and labeling the side of the box that is glued or adding a "point-of-entry" label so a Soldier knows which side is easier to open.

Lessons Learned: For the containers, the amount and type of glue was crucial to how easily the box could open.

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B.28 Low-Cost TRICON Latrine (LCTL)

TRL: TRL 5. Needs further testing through extended deployments.

Standardization, Interoperability: System must be designed into the respective latrine system, or a new centralized system must be developed.

Tailorability, Modularity, Versatility, Scalability: Must be scaled to the waste throughput requirement. Modularity is dependent on the type of system built. Decentralized will be built with the specific number of commodes and resulting throughput. Intent is for centralized latrine system to support a 150-man camp.

Net Ready: NA

Manpower: Net reduction in manpower, due to reduction in waste backhaul activities, though additional manpower required for maintenance.

Personnel Capabilities: Not known if new MOS is required for maintenance of this system. Will be determined by Combined Arms Support Command.

HFE, Complexity: In principal, incineration of waste is very simple. The complexity lies in the computer control of the system, ensuring that the combustion process operates without failure and successfully turns all waste to ash.

System Safety: The incineration process must remain controlled, to mitigate overheating and fire. System shall shut itself off in an intelligent manner. Built-in fire suppression should be considered.

Health Hazards: Emissions from the incineration process will have to be evaluated for Occupational Safety and Health Administration and Environmental Protection Agency requirements. Systems will be designed with exhaust "scrubbing" if needed. Heat from the combustion process will also mandate a delay between operation and maintenance.

Training: Additional training will be required for maintenance tasks. No training required for use, as the system is computer controlled and autonomous in operation.

Survivability: Selected technology does not degrade base camp or Soldier survivability.

Reliability: Reliability may be a concern, as the system provides additional capability.

Availability: TBD

Maintainability: System will require maintenance, specifically the removal of ash.

Sustainability: As long as fuel and common replacement parts are available, the system should be sustainable by Force Provider assets.

Supportability: TBD

Deployability: Conforms to the Force Provider TRICON standard.

Transportability: Conforms to the Force Provider TRICON standard.

Impact of Footprint: A centralized system will require additional space, plumbing and power. Decentralized shall conform to TRICON standard.

Cost/Affordability: System cost will be higher than a passive latrine system, but will likely pay off in water and energy savings within a couple years (TBD).

Soldier Feedback: NA. Latrine waste incineration has not been demonstrated for Soldiers.

Lessons Learned: Incineration is an effective method of remediating waste. It also consumes a significant amount of fuel to continue the combustion process. If the system can remediate 3 gallons of blackwater waste for every gallon of JP-8 consumed, amount of convoy operations will be reduced. The larger the system (i.e., a centralized system), the more efficient the incineration process.

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B.29 Onsite Automatic Chiller for Individual Sustainment (OACIS)

TRL: Following the July 2015 demonstration at the BCIL, the OACIS is at TRL 7: "System prototype demonstration in an operational environment". The final design toward TRL 8 has begun and will manifest as a 4th-generation prototype in the autumn of 2015. Transition to

Product Manager - Force Sustainment Systems (PM-FSS) and Force Provider (FP) via the Combat Feeding Directorate (CFD) NSRDEC Food Service Equipment Team (FSET) is pending for FY16.

Standardization, Interoperability: OACIS can be powered by 110/220 VAC and/or solar photovoltaics. It can operate simultaneously on shore and solar, prioritizing solar, using shore only to supplement. The container insulation is thick enough the system may be left unpowered at night without a significant increase in bottle temperature; thus when on solar only, there is no need for batteries or connection to a camp grid.

Tailorability, Modularity, Versatility, Scalability: The OACIS demonstrated versatility with respect to power sources. During the demo it was powered by four different power sources - camp power, the solar shade packaged with the system, the MANGEN (1kw man-portable genset), and the Solar Power Shade System mounted on top of the Tactical Operations Center shelter.

Net Ready: The OACIS has no network capability.

Manpower: Manpower requirements are limited to setup, loading bottles, and occasional inspections to make sure it is operating properly.

Personnel Capabilities: No new MOS should be required to operate or maintain the OACIS. Soldiers with MOS 91C (Utilities Equipment Repairer) would likely have the skillset required to make repairs.

HFE, Complexity: Few HFE anomalies were identified at demonstration. One concerned loading the unit from the top. For short people, a ladder and/or a buddy might be needed. But taller people had no problem loading bottles through the top without assistance of another person or a ladder. A short person could probably load it with a 1-foot step-stool. The other issue is placement of the operator control panel with LCD screen so low to the ground that it is hard to view and operate.

System Safety: The vendor noted that the electronics hardware has the capability to shut down to protect itself when it sees certain oddities in the power supply; however, the behavior is not completely mapped. The system also has a tilt sensor to shut the system down and avoid damage if the unit is tipped or falls over for some reason.

Health Hazards: There are no unique health hazards associated with operating or maintaining the OACIS. As with all electric systems, personnel must use caution to avoid electrocution.

Training: No formal training would be required for operation of the system. Instructions would be contained in an appropriate Technical Manual. Maintenance of the system may require some training. Failure modes and common repairs have not yet been identified.

Survivability: The unit demonstrated appeared fairly rugged. It is not known how the unit would fare in a CBRN environment. However, some of the contents could be protected from contaminants in that condition.

Reliability: The system is expected to be reliable. It was designed to operate for 10 years without a major failure. Specific parameters have not been determined through durability testing, but a couple of units have been running 24/7 for more than a year at NSRDEC.

Availability: The system is expected to run continuously.

Maintainability: The system is expected to be maintainable. The system itself requires no maintenance; however, there might be dusty conditions where the condenser fins might need to be blown free with compressed air. And it might be good to wash out the interior with a garden hose occasionally under the same dusty conditions, or if a bottle of a sticky beverage were to burst inside. Specific parameters, e.g., MTBF, have not been determined through log demo or other Developmental Testing.

Sustainability: The system has no sustainability requirements other than a power source.

Supportability: The system has no supportability requirements.

Deployability: The system should be shipped in a container with other unit equipment. It can be mounted to a standard pallet. The system weighs 750 lb empty.

Transportability: The system could be shipped in a container or transferred to the bed of truck for in-theater movement. A small forklift will be required for placement.

Impact of Footprint: This system would be additional equipment for the unit. If desired to deploy, deployment/transportation assets would have to be dedicated and space in the base camp allotted. The system is 79” tall and 44” x 44” at the base. A 90-square foot area would provide a 3-foot perimeter around the system for Soldier access.

Cost/Affordability: $16,000/unit in quantity.

Soldier Feedback: *Demo 1, BCIL, 300-man camp (542d Quartermaster Company - Force Provider)*

The Soldiers were asked to first discuss their current hydration practices. They said that a majority of Soldiers drink only plain water; however, they would potentially choose a different beverage if they had other options (e.g. Gatorade). Some of the Soldiers then commented that although they may not have Gatorade, they are able to make flavored beverages using the beverage base found in MREs or in the DFAC if they want it. They said "it's nice having the option. It's a morale booster"; "Flavored water is a quality of life thing. Especially down range. It's a comfort that you wouldn't normally get." They then said that if morale is higher "you get more work done." One Soldier, however, was concerned that if Soldiers have alternative drink

options, Soldiers would often choose the options that are not water and "you don't want Soldiers to just drink Gatorade all day."

When asked what Soldiers typically use in the field to drink water and other beverages, they said about 50% of Soldiers drink water from a CamelBak and about 50% of Soldiers drink water from a canteen. Gatorade and other beverages would usually be purchased in bottles from a PX or brought with them. They said bottled water is also used, but a "water buffalo is more common than bottled water. It's usually a personal bottle that you refill or a canteen." Some of the Soldiers then explained that when a water buffalo is first filled, the water is cold; however, it warms up once it is sitting in the heat, which is why it would be placed in the shade if possible. Conversely, one Soldier said that the water he has had from water buffalos has always been "cold or fairly chilled" because it takes a long time for the heat to warm up 500 gallons of water. He said that "even when it [water buffalo] was sitting for three days it was still cold" and that the water he drinks out of his canteen is warmer than the water from a water buffalo. One Soldier replied to this saying that "in the field it [water buffalo] is going to sit for days, so it will get warmer. In training, it gets refilled every day." The Soldiers then said that because of the risk of contamination, they were not allowed to add ice to the water buffalos: "If there's one bag that was contaminated, you contaminated 500 gallons of water." The Soldier who had been deployed shared that she was on a small FOB and drank bottled water but "you were lucky if you got a cold bottle of water. They had water all around sitting in the sun." They said that having cold water to drink is about quality of life for the Soldiers. The Soldiers felt that some Soldiers are conscious of how much they are drinking throughout the day, while others "don't drink until they are thirsty, which is too late." Because of the potential dangers of dehydration, they said that "people are always walking around reiterating to 'make sure you're drinking'" and "there are always people trying to make people drink."

The Soldiers were then asked how they envisioned the OACIS being used. They said that on a 300 personnel camp, only one to two systems would be needed: "two for convenience, but could just use one." And because "it's a nice size, the mobility of it is easy, you could move it if you want to." The Soldiers thought "they'd definitely be used big time" and could be placed by base camp entry points, the kitchen, billets, gym, and TOC. Because beverages would be stored in the OACIS, the Soldiers thought it would save space in the kitchen because "if you want a cold drink, you usually have to talk to the cooks to get it out of the refrigerator." Next, the Soldiers said they liked that the OACIS could be run using solar panels because it "saves fuel, time, energy, and noise from generators." Additionally, they thought that the solar shade used for the OACIS solar array could help to improve quality of life for Soldiers because it would become a spot that Soldiers could gather to find shade and "hang out." Some of the Soldiers were surprised that the OACIS (or similar system) has not already been used in the field because "they're low energy usage and they're going to be a huge morale booster."

Next, the Soldiers discussed potential modifications and recommendations for improvement to the OACIS. Some of their recommendations included partitioning the inside to separate types of beverages (e.g. water from Gatorade), adding a section underneath the system for cases of water, and adding a foothold to make it easier to load the system from the top. The Soldiers thought that sectioning off the inside of the OACIS would prevent Soldiers from "digging around for stuff" and would make it easier for them to grab beverages. They also thought that adding a section

with a door toward the bottom of the OACIS would be beneficial for storing entire cases of water (or Gatorade, energy drinks, etc.) so that individual bottles do not always have to be put into it. One Soldier gave an example of going out on a convoy and instead of having to take individual bottles, the Soldiers could just take an entire case of cold water. They also thought that being able to store cases of water would be beneficial because it would help to save space in kitchen refrigerators.

The Soldiers were asked what they thought about adding a bulk tank with water and a spigot to the OACIS in order to refill CamelBaks and canteens. Most of the Soldiers preferred keeping the OACIS just for bottled beverages and not adding a bulk tank because "it would get used up too fast" and "even if someone wants to fill their CamelBak, they can use the bottles and fill it." One Soldier also did not like that the bulk tank would take up space that could potentially be used for other beverages (e.g. Gatorade). Another Soldier did not like the idea of a bulk tank because they have a water buffalo if they want to fill CamelBaks or canteens or they can just grab bottles from the OACIS and use them in place of their canteens. Other Soldiers liked the idea of being able to pump water into an OACIS bulk tank from either a water buffalo or the water from air system so that Soldiers in the field could always have a source of cold water.

The Soldiers were asked what size bottles they prefer the system be designed to hold. The Soldiers said they would like 16.9 ounce bottles because they are "easy and fit in place of canteens. You can put them into cargo pockets and can transport them easily." There were no concerns about 16.9 ounces being too small because "if you want more, you can just grab two."

Lessons Learned 2: *Demo 1, BCIL, 300-man camp*

The OACIS performed very well during demonstration. The Technology Provider operated the system during the demonstration and collected many notes and lessons learned on system operation. Some of these lessons are paraphrased here:

- About 20 bottles per OACIS fell to the gravel during the initial loading. This was due to technique or haste.
- Only one bottle popped out of one of the OACIS dispensing ports while the units were being loaded.
- Once, the Technology Provider allowed a bag to fall in with the bottles, so he had to get on the ladder to get it out.
- Even a tall person seems to prefer to use a ladder to load. The Technology Provider was able to load without a ladder, but it was more difficult.
- Ease and difficulty of loading by pouring a package of bottles in through the top varied with the type of packaging. When almost full, it can be hard to dump the bottles out of the packaging.
- Once with each OACIS, the Technology Provider had to get on the ladder to push the bottles around so the lid could close.
- The north, east, and west portal plugs on the third-generation unit are too loose.
- The tightness of the plugs varies with temperature.
- It would be useful to have the forktruck pockets taller so people could stick their foot in there to see into the top.

- Soldiers that walk up to the OACIS for the first time don't know how to get inside. One Soldier reached for the forktruck pocket to pull on the lower panel.
- There was a good deal of caving. The ports could often be completely emptied before the bottles would shift on their own. We took it upon ourselves to break the bottle congestion. It was neither difficult nor did it present a danger.

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B.30 Containerized Ice Making Technologies (CIMT)

TRL: The Tiax prototype Containerized Ice Machine (CIM) that showcased CIM technologies (CIMT) at the Devens SLB-STO-D demonstration in June of 2016 has a recommended rating of TRL 5 based on: "The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment." The Rocky Research unit which was not ready for the June 2016 demonstration, will be ready for TRL 6 validation this coming summer. It is therefore rated a 5/6 based on: Fabrication completed in October 2016 of a "representative model or prototype system, which is well beyond that of TRL 5", and entry for testing in a "relevant simulated operational environment" beginning in November 2017 at the Nevada Automotive Test Center.

Standardization, Interoperability: The Tiax and Rocky Research prototypes require no unique tools. All electrical components, fasteners, and subsystems (such as the refrigeration system(s)) adhere to common industry standards — even if they are bespoke and contain advanced technologies. Communication ports conform to Institute of Electrical and Electronics Engineers standards. While as many parts as possible are COTS, some parts are custom. Many are fabricated from commercially-available pre-formed stock materials, such as steel strut or aluminum T-channel systems. Others originate from relatively formless staple stock. Likewise, subsystems are COTS whenever possible, but some — such as electronics, variable-speed drives, or thermal expansion valves — are from the developers' proprietary product line, or — as is the case with the bagger — were developed by suppliers specifically to meet the needs of the military application. Operators and maintainers would be trained to use the firmware in the onboard electronics to diagnose issues, but are not expected to maintain the firmware itself. This system isn't any more complex than many other military systems.

Tailorability, Modularity, Versatility, Scalability: Initially the customer's requirements for a CIM called for 3600 lb/day from a 20' ISO container. This was considered an improvement in terms of modularity relative to the existing solution for field ice making which is small units (manufactured by Hoshizaki) that could only be used within air-conditioned tents, required conditioned water, and did not bag the ice. All CIMT (6.3) and Containerized Ice Making Systems (6.4) developers have now settled on ISO TRICONs as the platform for purposes of greater modularity. When three TRICON ice machines are connected, forming a 20' ISO footprint, they meet the 3600 lb/day ice production requirement. In addition, a 20'-unit can also be assembled from two TRICON ice machines and one TRICON freezer. Such a beast would on-net handily exceed the requirement since each TRICON would be capable of storing 1,200 lb of bagged ice. The Rocky Research prototype is designed to produce 3600 lb/day within a single

TRICON, and store 1200 lb of bagged ice onboard. There is a question of what the Army camp model, against which new technologies and capabilities are compared, will use as a baseline. It could use ice that is shipped in, or it could use the Hoshizakis, or a combination.

Network Ready: The CIM project does not require network capability. However, for purposes of improving data visibility during testing of other units, we have often installed WiFi or cellular capability. It is likely that Rocky Research will install communication equipment in their prototypes. During field operation, it is expected that similar communication capabilities are well within reach to enhance interoperability with smart grids, to be used for peak shaving or load leveling, but it is too soon to settle on a configuration. Configuration guidance is on the way, however. The publication of the Tactical Microgrid Standards Consortium (TMSC) regulations for net readiness and interoperability for communications is due in 2018. There is a draft of the document in existence. Two informative links regarding the TMSC are:

https://community.apan.org/wg/tactical-microgrids/p/howtoparticipate
http://www.slideshare.net/sandiaecis/83tmsc-overviewbozadaeprisnl-microgrid-symposium

Manpower: It is possible for one person to operate this equipment alongside their other duties. This person would at the very least empty the storage buffer as required or three times per day. At full-rate production it will produce and bag 1,200 lb of bagged ice in an 8-hour period, and it can store 1,200 lb. Therefore, in the absence of other consumption, some of the ice would need to be relocated to another storage location to make room for continued production, or the unit would shut down automatically to await space to be freed up. These machines are otherwise intended to run entirely without intervention. Therefore, an operator's CIM duties would be to periodically check certain readings or functions to make sure everything is going well. Some issues will be resolvable easily, while others might require more involved mechanical intervention.

Personnel Capabilities: No additional MOS is necessary. The only one needed is a refrigeration mechanic (91C) in the event there is a problem. A person operating, monitoring, and maintaining the system on an ordinary basis will need no special qualifications.

HFE, Complexity: The Tiax and Rocky Research control interfaces were designed to promote effective Soldier-to-machine integration for optimal total system performance. The only other interface between the Soldier and the machine is the bagged-ice storage area, with which interaction is as straight-forward as can be imagined.

System Safety: Safety risks to the equipment are commonplace and no different than similar systems with mitigation plans in place. For example: the operating voltages range from 110-240 VAC; all components meet United Laboratories (UL) and National Electrical Code specifications such as insulated contacts, properly sized wiring and relays, and fuses or circuit breakers; some components, either through their construction or their enclosures, meet National Electrical Manufacturers Association 6 for dust and water ingress; and the control firmware includes logic that protects the machine, mechanically and electrically.

Health Hazards: The risks to humans presented by this system are commonplace and no different in severity, frequency, or likelihood than similar systems with mitigation plans in place. For example, there are moving parts, but guards bar inquiring appendages; there are standard voltages present throughout the system with insulation and fuses preventing electrocution; and equipment has been designed with NSF International specifications in mind, as well as cleaning procedures, to prevent illness from organics.

Training: When trained to established standards, Soldiers representative of the target audience population with the required critical skills, knowledge, and abilities are able to perform all critical tasks safely, with no exposure to uncontrolled health hazards. Training materials can be easily developed, and the level of effort to train personnel for various tasks is not significantly different from similar systems.

Survivability: While the CIM does not degrade base camp or Soldier survivability, and is hardened for extreme weather and rough transportation, it is unlikely to be designed to operate in a CBRN environment.

Reliability: The system is expected to be as reliable as current systems in use. The refrigeration system is specifically expected to be much more reliable than other refrigeration systems, due to variable-speed motors that eliminate extreme mechanical forces and electrical inrush. As for the rest of the system, it is expected the automatic bagger will be the most challenging subsystem to design to achieve normal MTBF targets, especially when operated after a rough journey; therefore, it will not be claimed that the system as a whole would be more-reliable, only "as reliable."

Availability: The system is expected to be always available. However, discussion is warranted. If properly stowed, a CIM would be sanitized and drained of water. It's possible a post-storage sanitization task would be performed prior to initiating ice production. If the system were not drained of water prior to storage, and it was stored in an area that experienced hard freezes, it is possible some plumbing repairs would be needed. If the system were not sanitized prior to storage, and/or it was not completely dried, it is possible additional sanitization tasks would be necessary. The Veterinary Corps has developed some biological contamination prevention protocols that might be useful for application to CIMs.

Maintainability: The system is expected to require some, but not excessive, maintenance. The bagger is a concern.

Sustainability: The technology is easily sustainable with the resources available to a base camp. To match and exceed the existing ice making capability at base camps, CIMs will save a large amount of fuel, and some water. They will draw less power as well; therefore, external gensets and camp grids can remain unchanged and still support the capability.

Supportability: The expendable supplies include plastic bags in which the ice gets stored, and possibly water filters. At full-rate production, and assuming 10-lb bags, though 20-lb bags could be possible, a CIM will fill 360 bags per day.

Deployability: Each CIM is contained, shipped and used within a single TRICON and weighs less than 8,000 lb. The container meets ISO specifications and will be designed for rough military transport, and is therefore capable of military or commercial transport by highway, rail, sea, or air -- and dirt road. A unit would need a 10K forklift to handle the 8,000 lb. The presence of such an asset at a camp is likely, considering that the target camp size is 600 persons and would therefore be well-equipped for lifting a variety of heavy loads.

Transportability: A single CIM will offset 5 of the current Hoshizaki ice makers. It is likely that 5 Hoshizakis would fit inside one TRICON, so there would be no savings if it was left only to that. However, because Hoshizakis require shelter and air conditioning, and that extra footprint is considered, there may be some savings to be found. It is hard to assess, because the air-conditioned shelters necessary to support the Hoshizakis will be multipurpose, i.e., used simultaneously for other activities, such as dining, food preparation, or medical.

Impact of Footprint: Because it expands during setup, the Tiax platform has an equipment footprint of approximately 80 sq ft. The Rocky Research concept does not need to expand, so it has an equipment footprint equal to the TRICON, 53 sq ft. Allowing a 4-foot circumferential corridor for access around each would expand them to 234 sq ft and 168 sq ft respectively.

For setup and packup of the Tiax unit, space is needed on one end of the TRICON to maneuver a small forktruck or other vehicle that could easily pull the framed cube containing the mechanicals out of the TRICON, and push it back in for pack-out. The above footprint does not include this extra bit of space, because it's considered temporary. Also, it is possible that a subsequent prototype could be designed differently so it can be manipulated by human power alone.

The addition of shelters, water bladders, or supplemental freezer space at the discretion of a Camp Commander would increase the area needed. The above footprint estimations do not include a situation where multiple TRICONs are connected. CIMs would likely only be set up next to kitchens, even though ice is used for medical purposes and outgoing convoys. Because the machines bag the ice, it is easy enough to transport elsewhere in a camp.

The spare parts needed for these units consist of water filters (if equipped), and plastic bags, so there is probably no need for large amounts of cargo or storage space.

This technology has no negative impact on the base camp space or logistics.

Cost/Affordability: A spreadsheet was created to determine the affordability of these ice producers. 160 of the CIMs are required to replace the 1,084 small units being used today inside tents to meet ice needs. Assuming the return on investment is due entirely to fuel savings, the full procurement cost of each CIM purchased will be completely offset in a period of 6 years.

Soldier Feedback: *Demo 2, BCIL (Infantry Squad, 82d Airborne Division)*

The Soldiers were first asked at what size camp this technology would be best suited and how much ice is typically used on a base camp. All of the Soldiers agreed it should be used on a base

camp with at least 150 personnel because it generates too much ice for a smaller camp. The Soldiers said "one wheeled patrol could use 200 pounds of ice" minimum and that every vehicle would have a chest of ice for medical use and to keep water cold. One Soldier said the system would likely be running 24/7 when there are three patrols and Soldiers using ice in towers. They then said "having cold drinks waiting for you in a tent or hard structure is a morale boost and it's a safety thing as well. It beats soaking a sock and hanging it off your side mirror." The Soldiers indicated the CIMT could be employed immediately upon establishment of a base camp; however, they said "if you're early entry, you normally don't have potable water" so the ice would initially not be consumable and could only be used for coolers. When asked about transport of the system, the Soldiers said they would like the technology to be sling-loadable.

The Soldiers were then asked if a specialized skill-set or training would be required to use the system. All of the Soldiers said it would not require an MOS-specific Soldier to operate because it is automated and simple to use. They also said cooks would likely be responsible for the system on a 150-person base camp. The Soldiers did not think formal training would be necessary to use the system because of its simplicity. One Soldier suggested putting pictures and instructions on the door of the CIMT to show Soldiers how to use it.

Next, the Soldiers discussed the durability, design, and safety concerns of the CIMT. All of the Soldiers agreed that any PVC (polyvinyl chloride pipe) in the system should be replaced with reinforced nylon tubing to increase durability of the technology: "It's [PVC] not durable over time because it's rigid and it can become brittle over time." Some of the Soldiers expressed concerns about it being a "tight squeeze" between the TRICON container and the mechanical frame and said they would need more space because they don't always have a truck to pull it out. They also suggested adding a winch system to help remove it because it currently has only a limited number of wheels. The only safety concern the Soldiers shared was related to sanitation of the ice storage area. Due to Soldiers needing to enter the storage area to get bags of ice, they were concerned about ensuring that area was always kept clean. Relatedly, one Soldier said "if you give more space inside the refrigeration to come out, if there are gaps around it during a sand storm, it definitely needs to be protected. Otherwise, dirt and dust are going to get in there and into the machine." The Soldiers emphasized that all components of the technology need to be "as sealed as possible" to ensure no dirt or dust gets inside.

The Soldiers then discussed likes and benefits of the system. They found the system to be convenient because it generates and bags the ice itself and liked that it can generate 3600 lb of ice per day. They said it would "alleviate strain on the DFAC (dining facility) or plus up the capability of the DFAC." Although the Soldiers liked the system overall, one Soldier said he was "hesitant to give it [CIMT] a thumbs up" because it requires potable water. This Soldier was conflicted because he would like the ability to use non-potable water in the CIMT; however, he was concerned about the potential use of contaminated water: "If you have well water and you don't have a person to monitor water quality… if somebody does drink or eat the ice, you affect operations because they get sick. If it's an Afghan well, it can have E. coli." Because of this, he said he would "like to see that system [CIMT] with RO filtration." Another Soldier then said "ice is made non-potable normally. It's not abnormal for it to be non-potable if it's just for ice chests. People wouldn't drink it or eat it." Some of the other Soldiers agreed that the requirement should be changed to not require potable water; however, it was noted that "once you hook that system

up to something that's non-potable, you have to flush it before you use it again with potable."

Lastly, the Soldiers provided suggestions for improvement to the CIMT system. Their main suggestions included having the system be able to hold more bags and adding a trough or "something to pour the water into so it could be reused in the system." They also suggested using 20 lb bags instead of 10 lb bags because they "don't have to move as many bags if they're 20 pounds" and would like that two Soldiers could carry 80 lb of ice instead of 40 lb. They further explained that "the whole point of this is waste reduction," so they would like reusable bags (if possible) or bags that are biodegradable.

Lessons Learned: Bagging ice is very difficult, which is why one contractor's contract is focused solely on that function. Keeping the interior clean, especially free of mold, is difficult, so all the developers have been warned. Details of lessons learned are in notes recording activities at the demonstration (see below).

Demo 2, BCIL

- In hot weather the batches might take longer than 10 minutes each. In cooler weather they might happen faster. Therefore, the system keeps track of how long each batch takes, averages the values, and adjusts the sequencing accordingly to keep the harvests separate. The software logic carries a rolling average of how long it takes to make a batch of ice. It then applies the average to determine when the next batch is allowed to start, i.e., the next unit is not allowed to start its ice making process until the average amount of time has passed since the start of the last unit's turn.

- If the freezer fails, ice production will stop when the freezer compartment rises to 80 °F.

- Manual intervention was occasionally required. A final production prototype will require no human intervention other than regular short-term tasks such as replacing the stock of bags or removing bagged ice from storage as needed, or long-term scheduled maintenance such as sanitation and descaling. However, this is a 1st-generation demonstration platform, and while it has been operated for hours at a time making ice without any interruptions, it turns out that there are many parts of the process that are prone to hiccups and therefore require babysitting to ensure the ice making and bagging processes go uninterrupted. The processes are so complex that really only Tiax has the ability to troubleshoot with any depth, but there are a few things that anyone can spot and remedy if trouble occurs. They are as follows:

    1) The white flippers at the base of the ice heads sometimes get stuck in the down position after an ice load has been dropped. This can be seen through the Plexiglas viewing panel. To fix, just give them a flip with your finger and they will pop upwards into the waiting state.

    2) The door that drops a fresh bag down out of the bagger onto a conveyer below sometimes gets stuck open. This is because the tension spring needs to be in perfect balance with the electromagnet that actually holds the doors tight against the weight of a bag. To fix, just give it a bump.

3) Sometimes the bagger gantry won't pick up an empty bag. This can be solved by placing a stick lengthwise underneath the stack of empty bags such that it creates a hump in the middle, bringing the top bag closer to the pickup rollers. Also, lots of little ice chunks bounce around the interior of the bagger, and when the bagger doors are open so we can watch or actively manipulate operation, these chunks melt. If they make a bag wet, the pickup rollers may not have enough traction.

- Ice left in the ice bin/hopper overnight clumped, so it took a while to clear before bagging could start.

- By the end of the day, the sensor that detects that the gantry has lowered the grabber onto the bag stack failed, stopping the ice machine in its tracks for the day. That sensor is a VX80 C1 Hall effect limit switch (obsolete and no longer available).

- The largest variable in the bagging is how long the bag takes to fill. Fill is accomplished by an auger pushing ice out of the ice bin. The rate of ice leaving the bin depends on the effectiveness of the auger, which depends on the depth of ice, shape of cubes, temperature, and any ice bridges that have formed in the auger.

- Called Tiax to report that the system was only running through one cycle, then possibly going into end-of-day mode due to need for defrost in storage area. Tiax came out, connected a computer to monitor details of operation, and started the day by changing the software program to enable freezer defrost. Defrost was supposed to begin every 24 hours of accumulated on-time, regardless of whether the ice production or bagger is operating. The timer is retentive, meaning if the system loses power, it still knows how long it has been since the last defrost.

- Tripped the circuit breaker that protects the exit ram. Put the machine in manual mode to analyze the movement of the bag movers and how they affect the bag. It turns out that a bag would drop through the bagger trapdoor and fall to the left. If this is the case, when the conveyer pushes the bag onto the elevator, there is ice and material hanging off the back side of the elevator. When this excess matter contacts the exit ram lower edge, there is a high probability of jamming. After a few attempts at modifying the limit switches and the configuration of the ram, we found that mounting a previously vertical piece of sheet metal to be instead horizontally on the ram would prevent the bag from leaning too much to the left, and when the conveyer got to the end of its travel, the sheet metal would push the bag so it would fall to its right on the elevator. This went a long way toward improving reliability of bag transport from the bagger to the storage.

- Unit 2 was taking too long to harvest because the cool weather was keeping the refrigerant too cool, so there was too little heat to melt the ice off the head. To solve this, Tiax shut off the condenser fan to increase the temperature of the condenser. The high-side pressure then rose to 100 psi. The flippers on Unit 1 got stuck down, because the long harvest time caused all the cubes to clump and the large chunks really got stuck in the flippers. Unit 3 was not harvesting, because it was waiting for Unit 2 to finish harvesting and no two units are ever harvested at the same time; therefore, we flipped the flippers on Unit 2 so that it would

believe it had finished harvesting and the system then moved on to Unit 3. The next issue was severe blockage in the spout of the ice bin outlet, because of the clumps of ice from Unit 1. Attempting to clear the blockage by hand caused a bag to be too full, and that caused the bag to be stuck during transport to storage.

- The system ran very well, producing about 30 bags in 2 hours until a blown relay brought everything to a stop. The relay was rated at 3 amps continuous, and 21 amps of surge. It controlled the conveyer motor which was designed to draw 1 amp, but is suspected of drawing 5 amps. The over-current eventually wore out the relay. Installed a new relay for the conveyer motor. The new one is rated at 7 amps continuous. The surge rating is unknown. It turned out that the relay failure had also caused a 10-amp slow-blow fuse to pop. A replacement for the very common barrel-type 0.25" x 1.25" fuse was unavailable, so the motor was wired through a different 10-amp fuse being shared with the water fill solenoids.

- Another issue is that the evaporator condensate tray drain was ineffective due to a crimp and a rise in the flexible tubing. When the condensate tray became full enough, the evaporator fan began skimming the surface and flinging water around the storage area.

- One day we had the "ice bin full" sensor disabled because if it gets a little bit of water on it, it will erroneously trigger a "bin full" signal. However, the bagger began to fall behind ice production, so we wanted to pause production, but without stopping the bagging. Pushing stop to initiate the pause mode pauses everything, so we instead re-enabled the bin sensor.

- Given how quickly the freezer coil frosted over, we set the defrost frequency to 4 hours. A large ice bridge formed in the ice bin, so even with plenty of ice the auger could not transport it to bags. We had to poke it with an aluminum rod so it would fall into the auger. Part of the fault is that we operate the system with the bagger doors open and without much cooling leaking from the freezer compartment. This is much less likely to happen if the inside of the bagger were kept adequately cool. Also on this day, the defrost cycle was changed to a frequency of every 3 hours.

- There was a period where the bagger continually insisted on picking up two empty bags at a time. Also, when the storage compartment was maintained at 19 °F, the un-toothed conveyer belt that transports bags of ice horizontally to the elevator had frozen and was slipping. A funny noise was heard in the electrical box, so we shut down. It turned out that the conveyer had frozen again, so we melted it with a hot-air gun. To solve this issue, Tiax will at some point reprogram the system so it exercises each of the three bag conveyers each time the storage compartment goes into defrost mode.

- A single bag weighed 8 lb. We noticed that the pile of bags in storage was getting so high that instead of each bag dropping off the chute, they were instead colliding with each other, tail to head, until they formed a zig-zag line down the chute leading to the top of the pile.

- One day, at startup, the exit ram jammed. It could not clear itself and we could not see what it was stuck on. Tiax ended up yanking hard on it, and it moved 3 whole inches, then worked fine thereafter. Also, the horizontal conveyer was frozen at first, but this time it freed itself.

- Noticed that the inside of the storage compartment smelled like chlorine.

- The actual water filling each reservoir is closer to 2.5 gallons. At first Tiax thought it was 3 gallons. The bag weight also is lower than the original target of 10 lb, because Tiax lowered the fill-eye to a more conservative level to allow a little extra head space in each bag just in case at the last second a huge clump of ice toppled out of the fill chute and prevented a bag from sealing properly -- though in fact we didn't see any clumping until almost the last day.

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B.31 Containerized Ice Making System (CIMS)

The CIMS was not demonstrated by the SLB-STO-D. For more information on this system contact the ***POC***: William Feather, PM E2S2, william.m.feather.civ@mail.mil, 508-233-4673.

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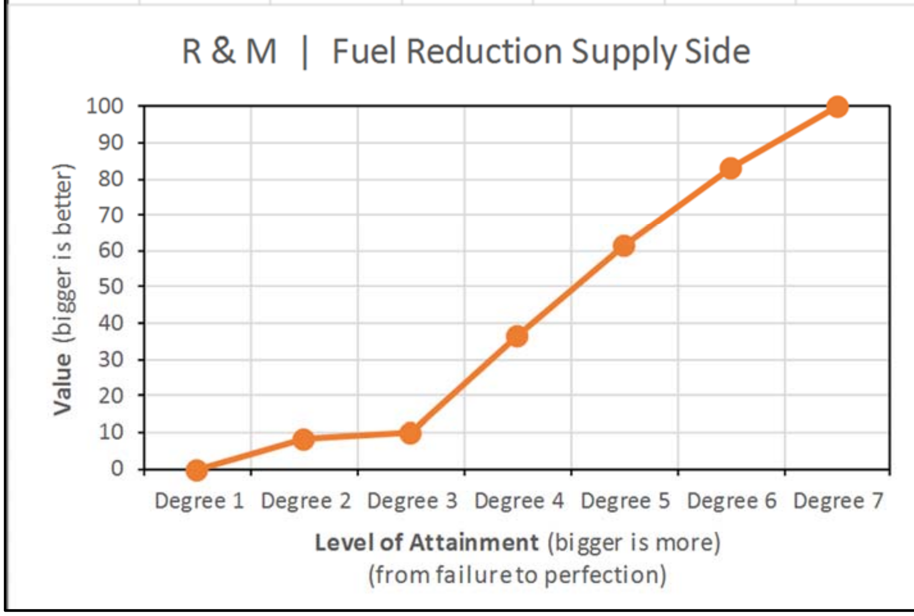
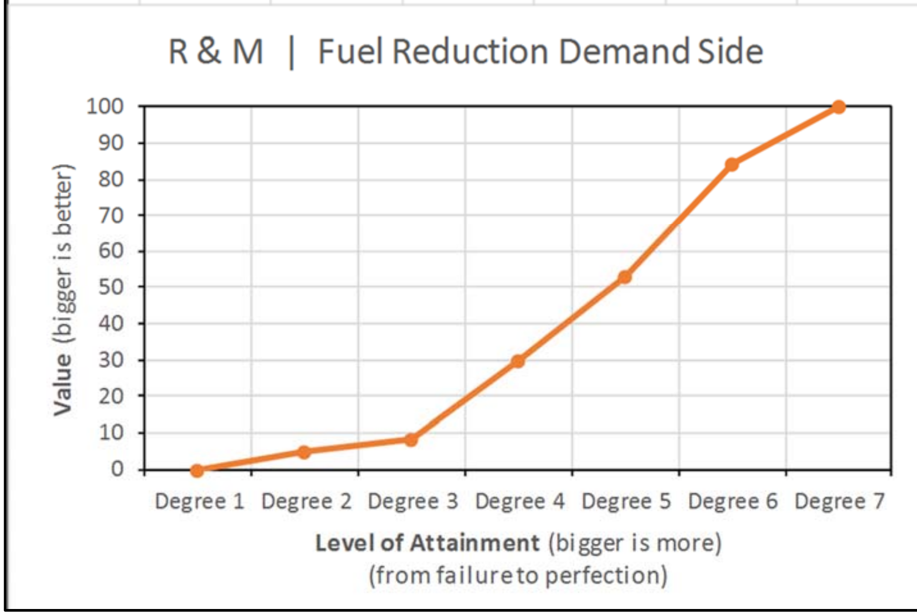
ANNEX C – VALUE CURVES

C.1 Readiness and Maturity

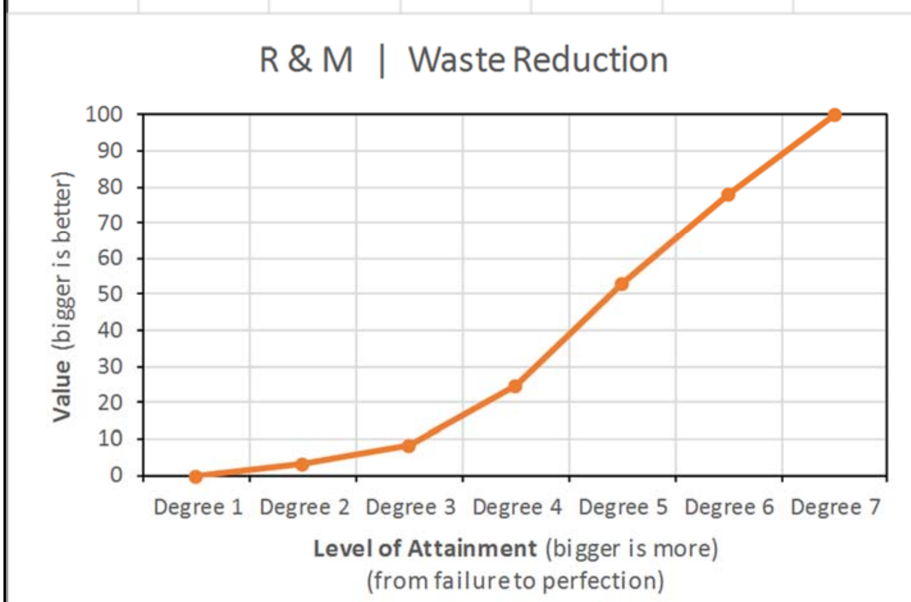
R & M | Fuel Reduction Supply Side						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	8	10	37	62	83	100



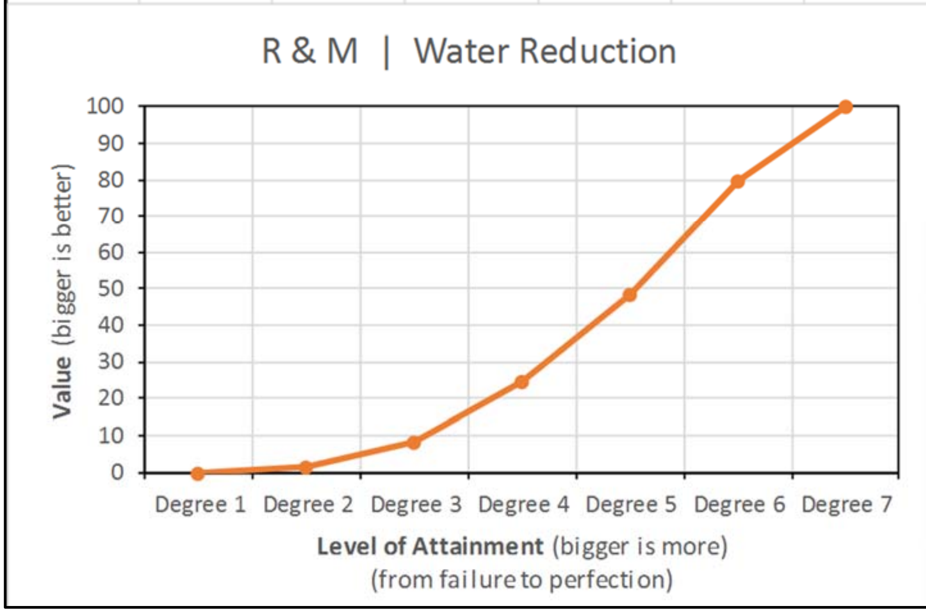
R & M | Fuel Reduction Demand Side						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	5	8	30	53	84	100



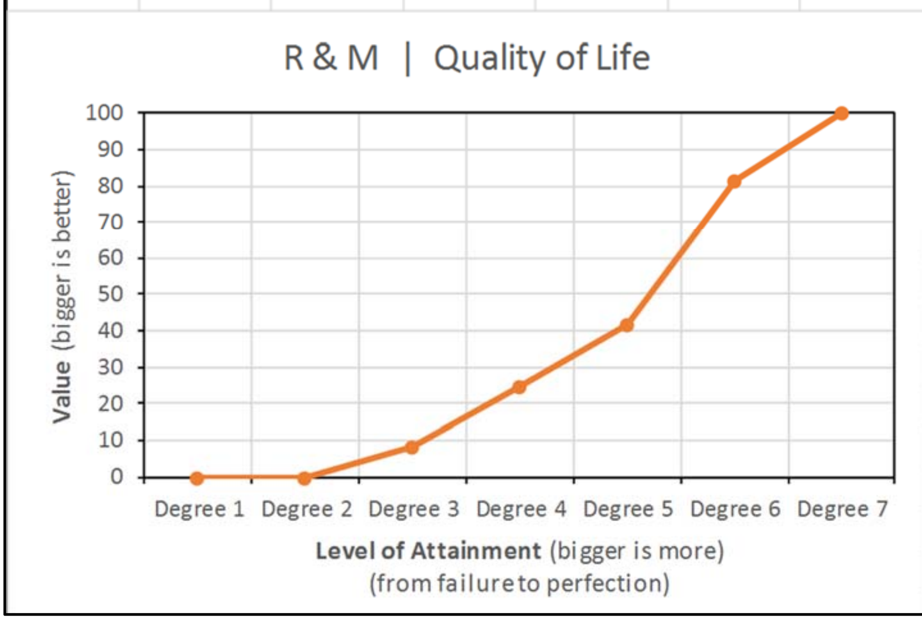
R & M | Waste Reduction						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	3	8	25	53	78	100



R & M | Water Reduction						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	2	8	25	48	80	100

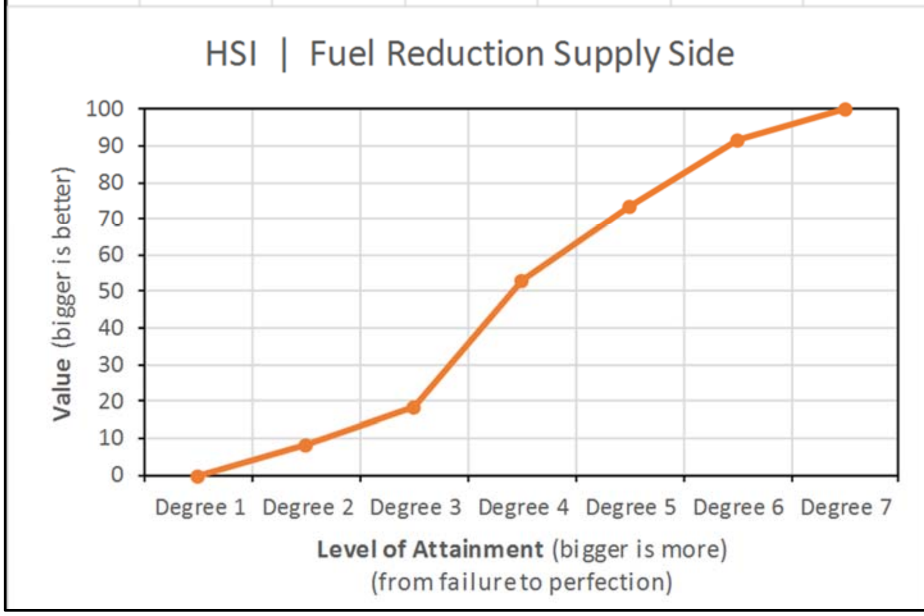


R & M | Quality of Life						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	0	8	25	42	82	100

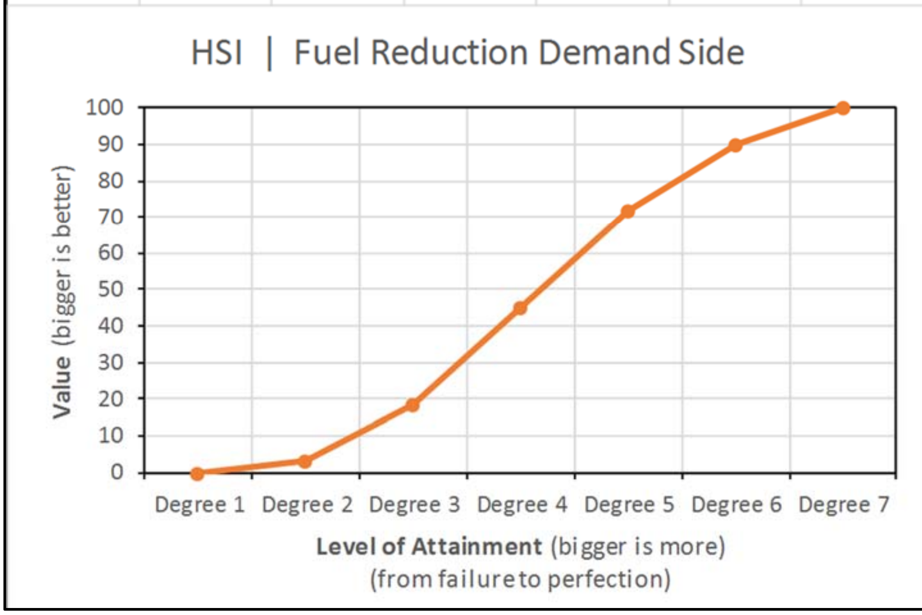


C.2 Human Systems Integration

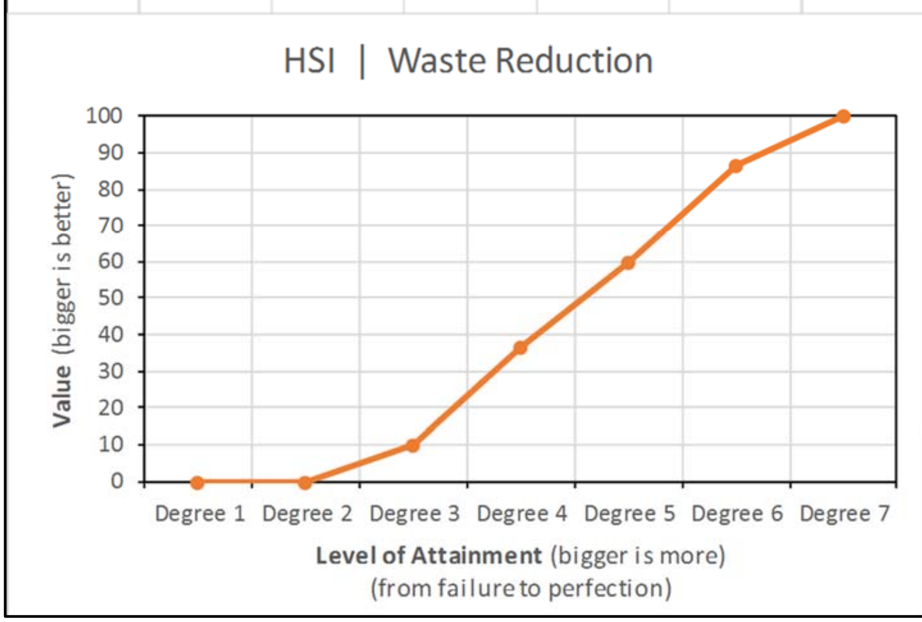
HSI | Fuel Reduction Supply Side						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	8	18	53	73	92	100



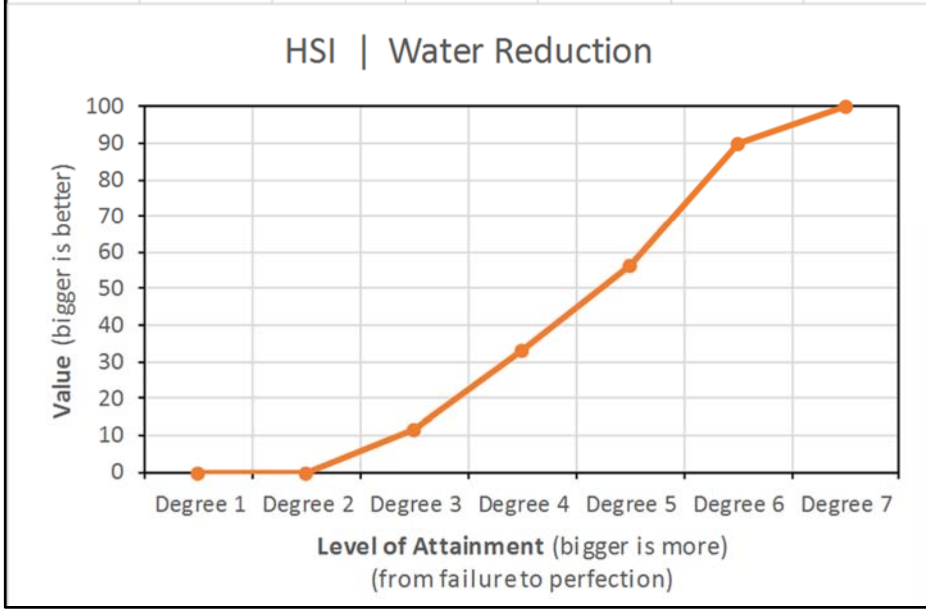
HSI | Fuel Reduction Demand Side						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	3	18	45	72	90	100



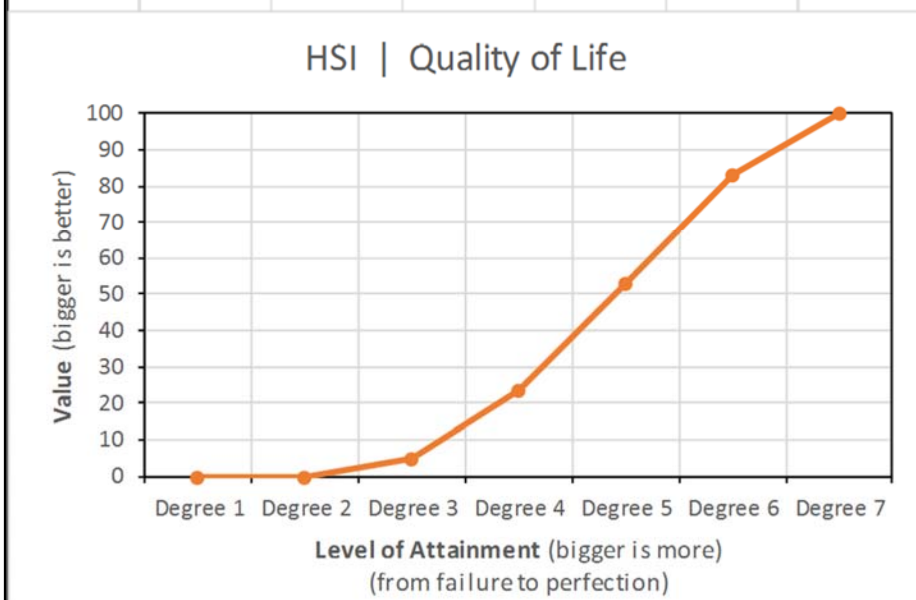
HSI | Waste Reduction						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	0	10	37	60	87	100



HSI | Water Reduction						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	0	12	33	57	90	100

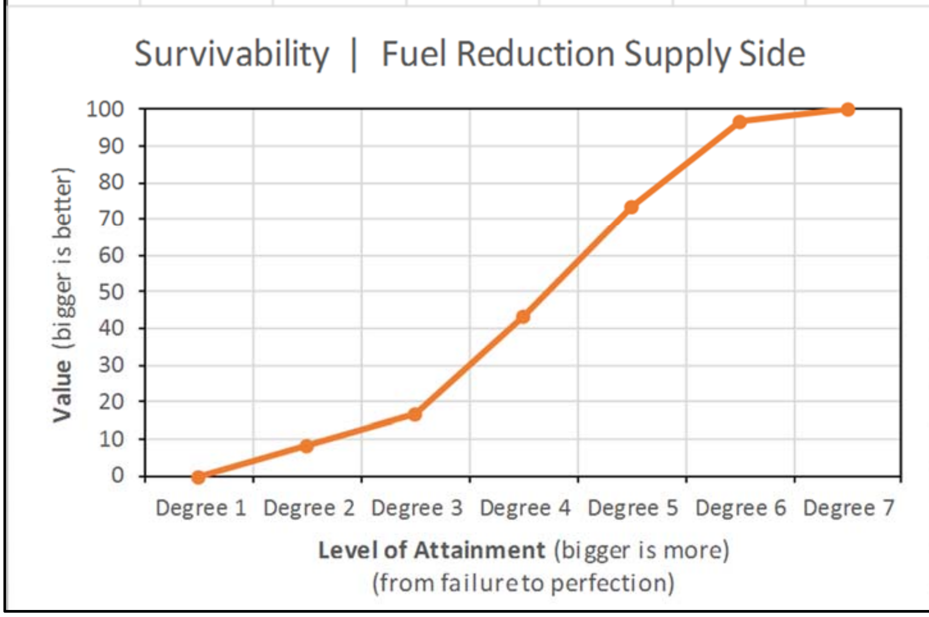


HSI | Quality of Life						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	0	5	23	53	83	100

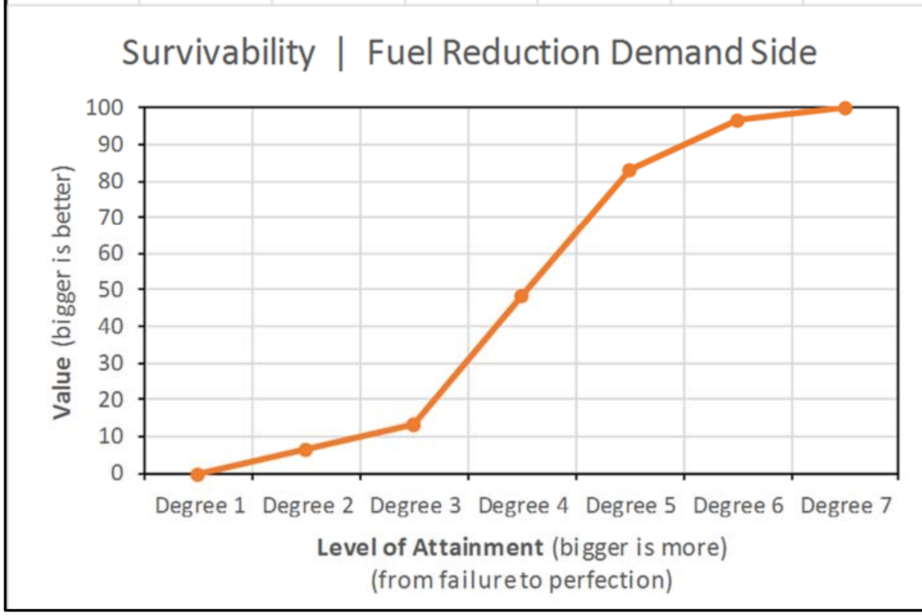


C.3 Survivability

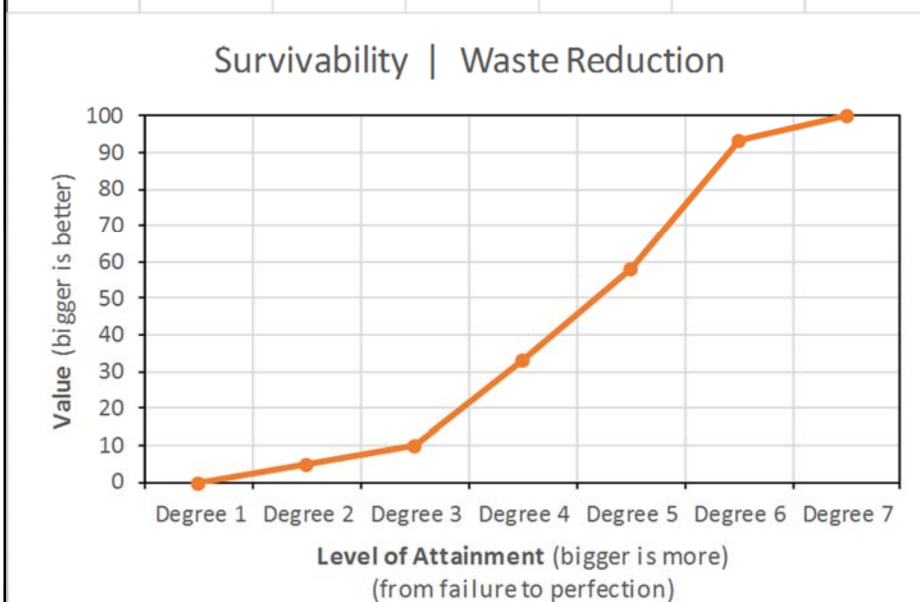
Survivability | Fuel Reduction Supply Side						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	8	17	43	73	97	100



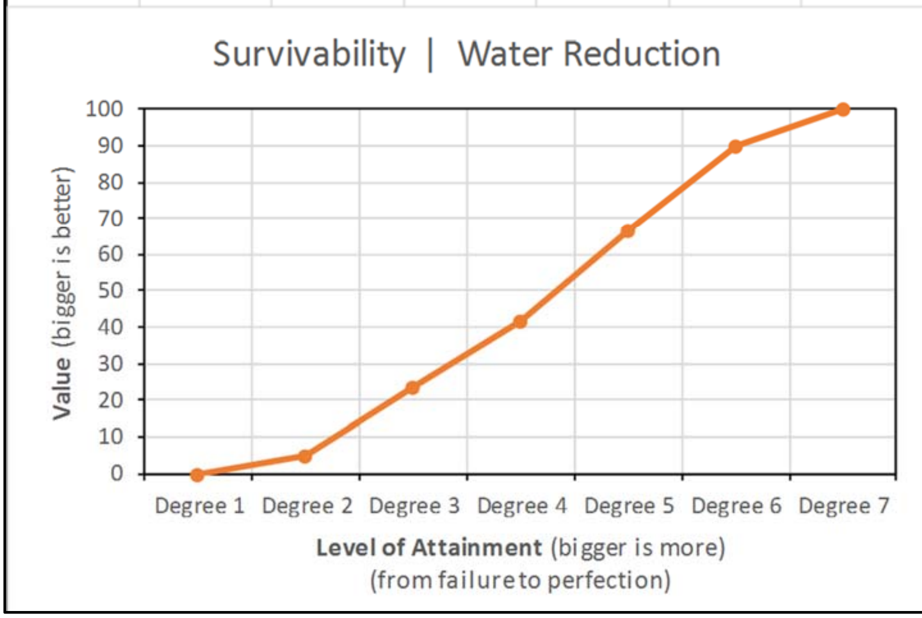
Survivability | Fuel Reduction Demand Side						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	7	13	48	83	97	100



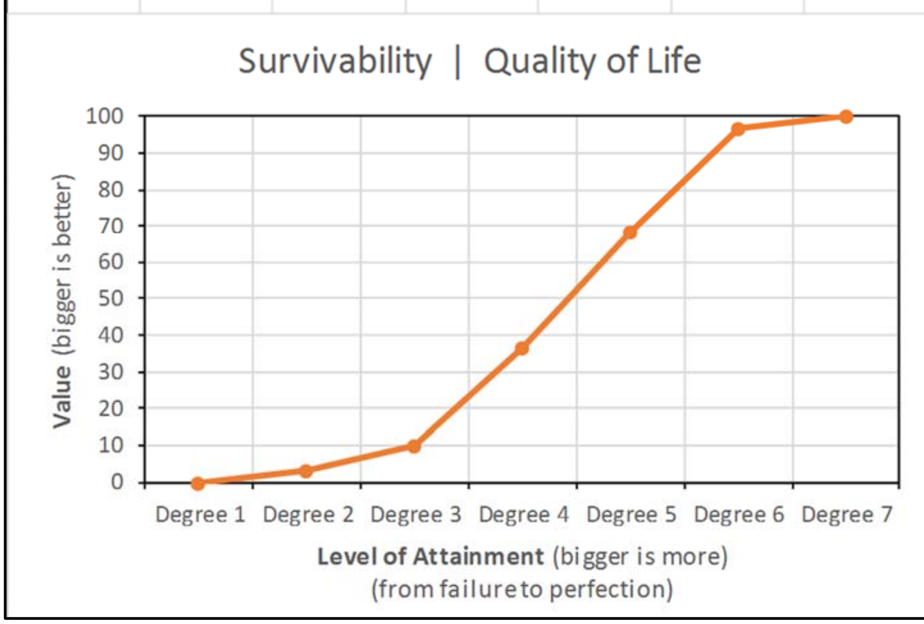
Survivability | Waste Reduction						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	5	10	33	58	93	100



Survivability | Water Reduction						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	5	23	42	67	90	100

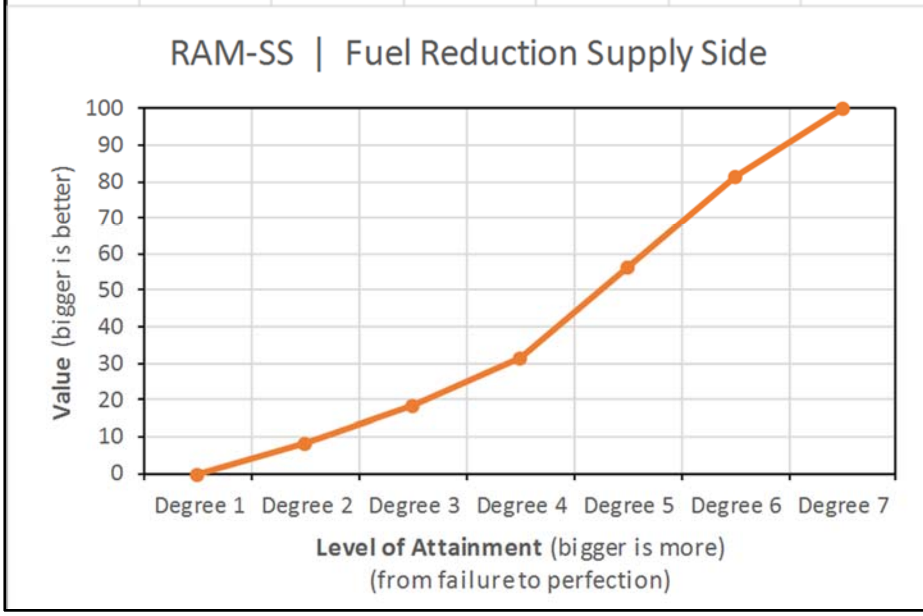


Survivability | Quality of Life						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	3	10	37	68	97	100

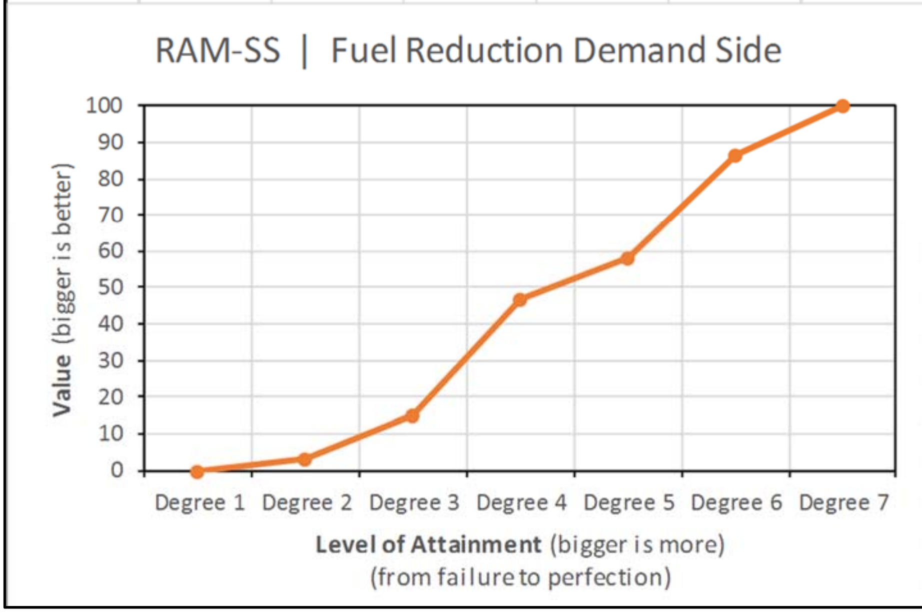


C.4 RAM-SS (Logistics)

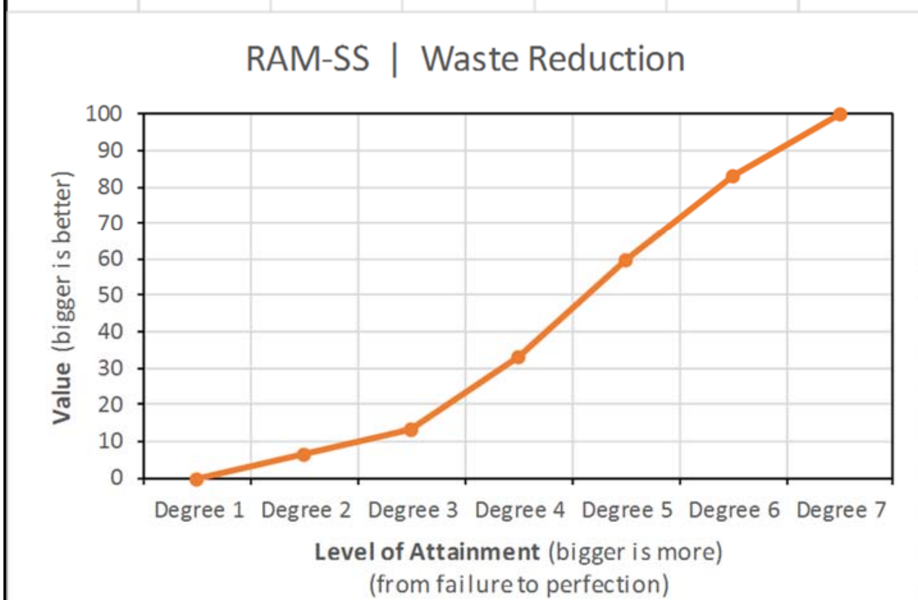
RAM-SS | Fuel Reduction Supply Side						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	8	18	32	57	82	100



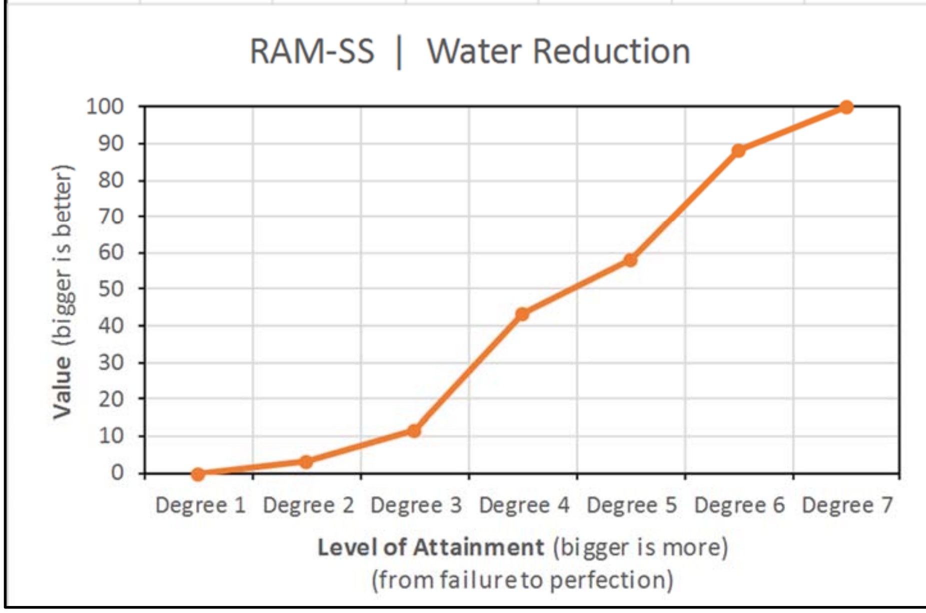
RAM-SS | Fuel Reduction Demand Side						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	3	15	47	58	87	100



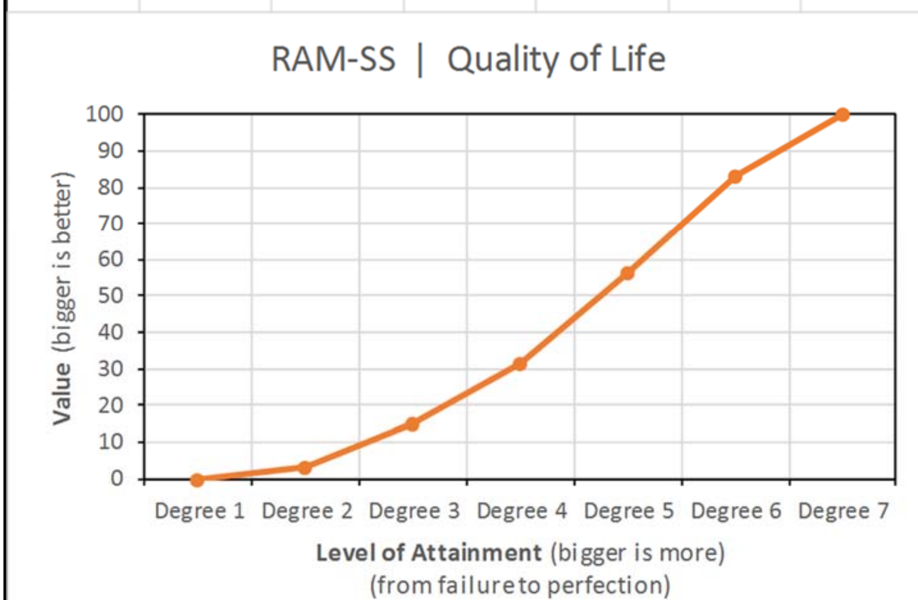
RAM-SS | Waste Reduction						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	7	13	33	60	83	100



RAM-SS | Water Reduction						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	3	12	43	58	88	100

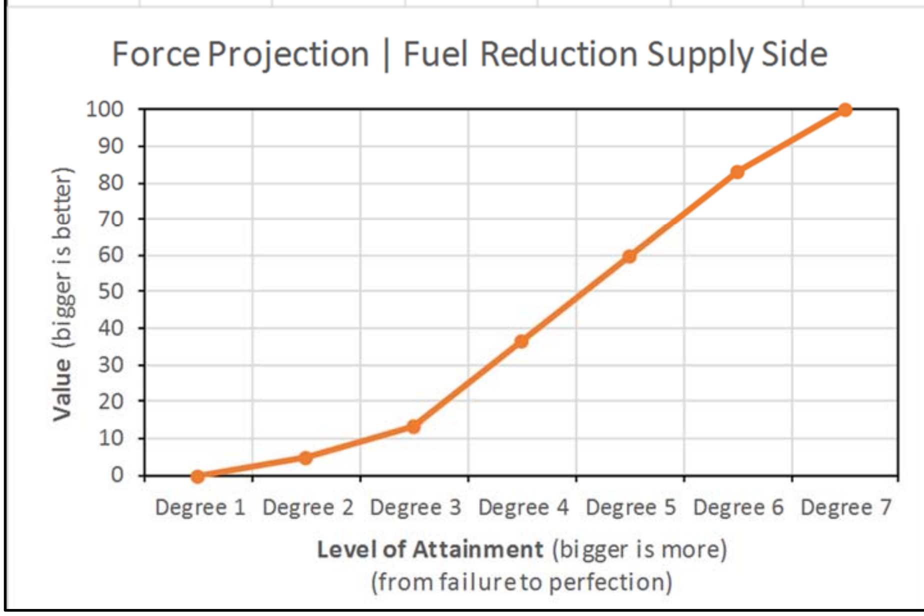


RAM-SS | Quality of Life						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	3	15	32	57	83	100

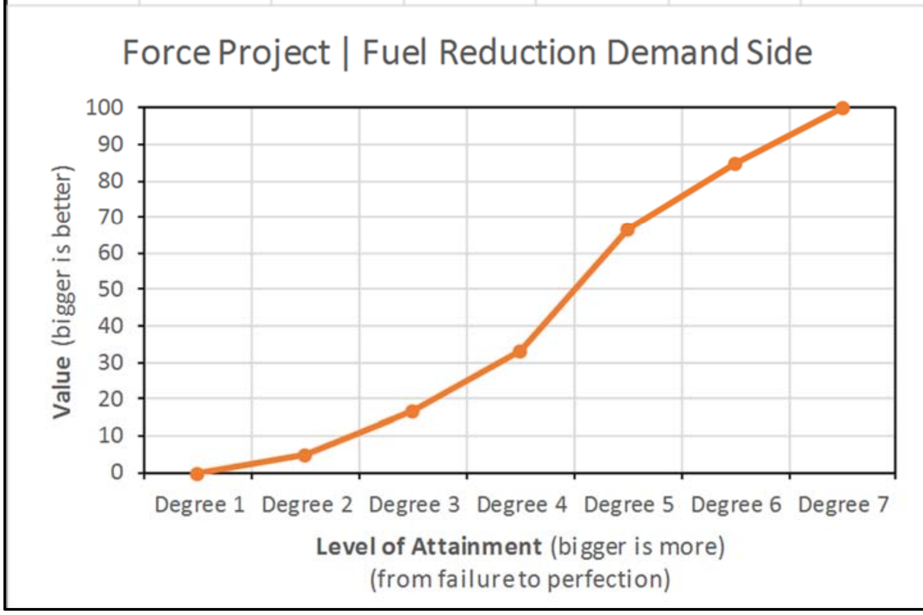


C.5 Force Projection

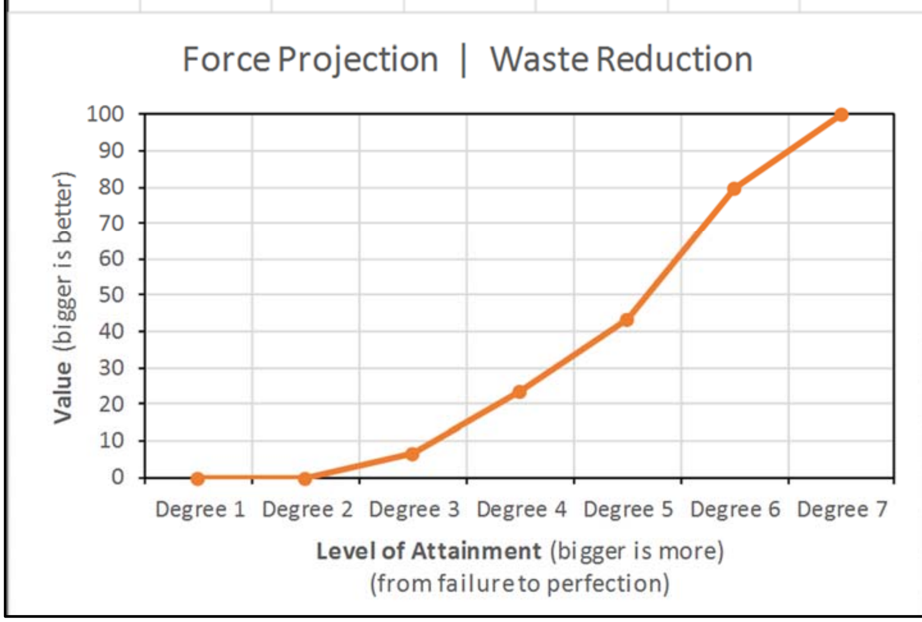
Force Projection | Fuel Reduction Supply Side						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	5	13	37	60	83	100



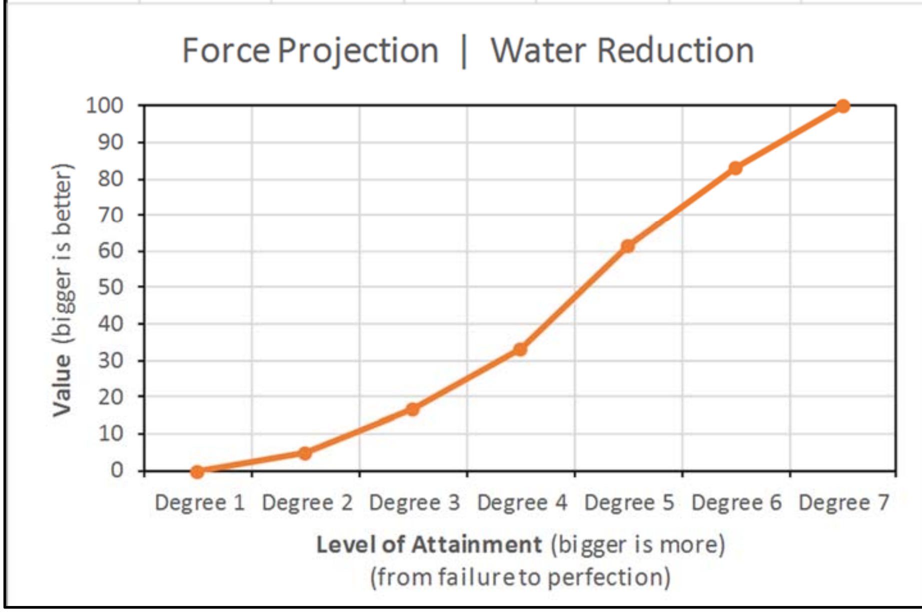
Force Project | Fuel Reduction Demand Side						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	5	17	33	67	85	100



Force Projection | Waste Reduction						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	0	7	23	43	80	100



Force Projection | Water Reduction						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	5	17	33	62	83	100



Force Projection | Quality of Life						
Degree 1	Degree 2	Degree 3	Degree 4	Degree 5	Degree 6	Degree 7
0	3	8	28	52	85	100